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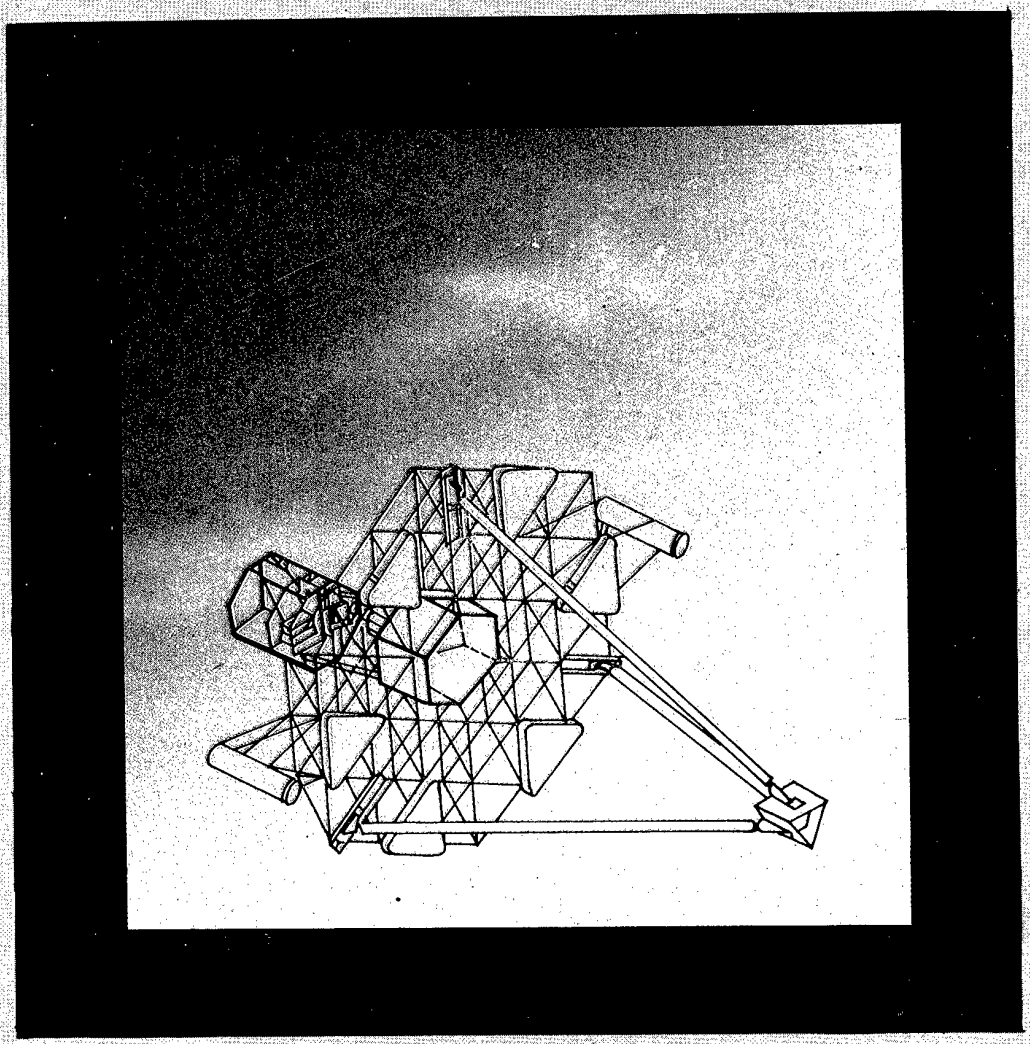

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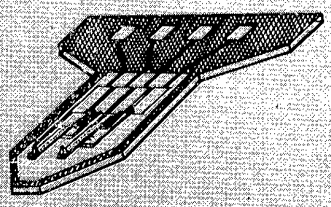

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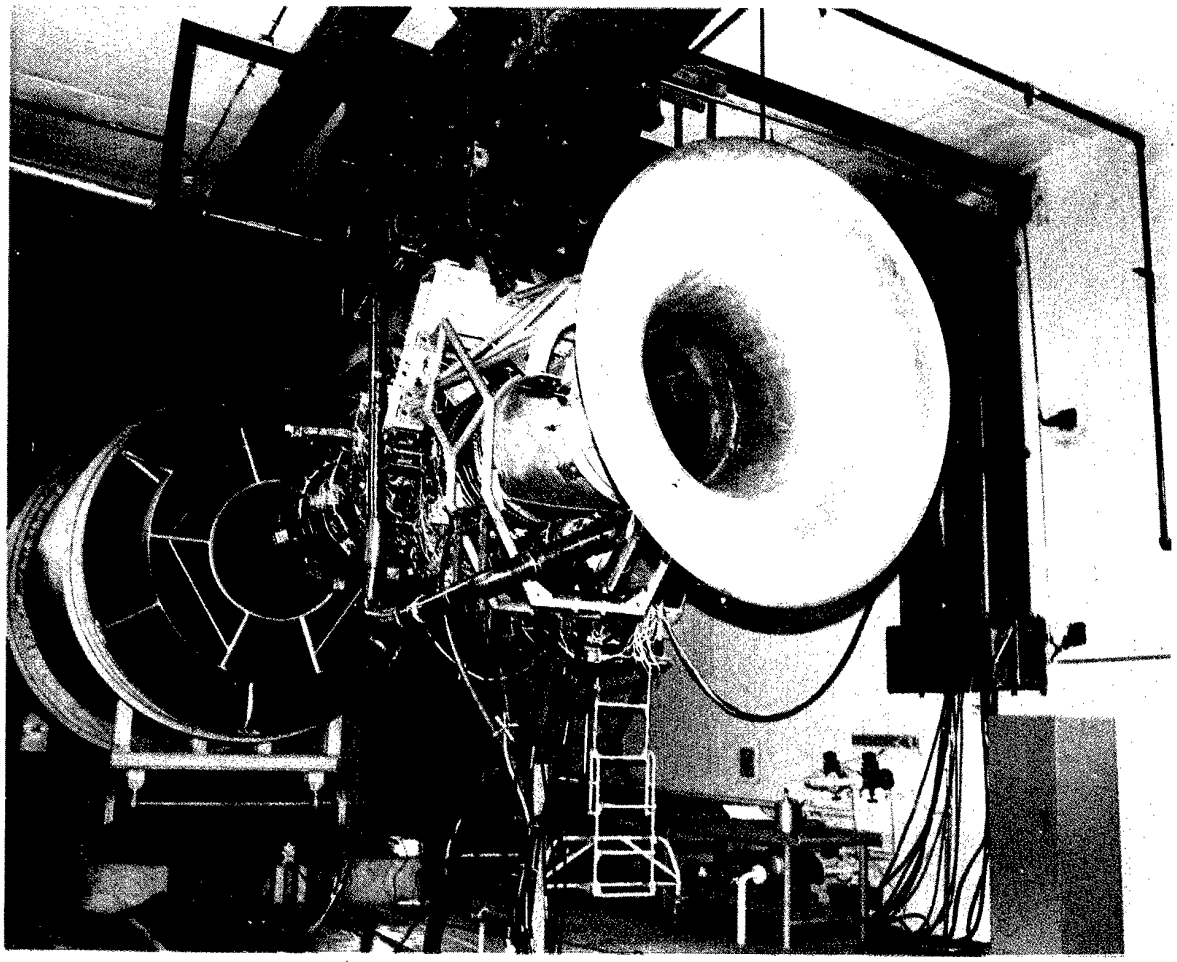

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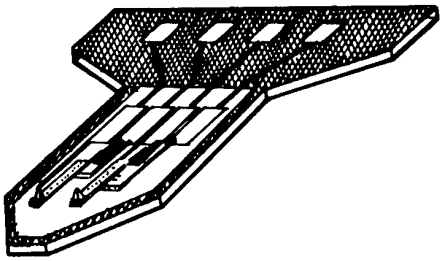

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डा० आ० प० जै० अब्दुल कलाम
Dr. A.P.J. Abdul Kalam

28 October,1996

MESSAGE

The field of MEMS and smart structures will lead us in realising some of the functions in micro sizes with a dream close to nature's marvel, evolution of human sensors.

A wide range of industrial and medical applications use silicon micromachined sensors. Applications of MEMS will dominate aerospace and military systems in next decades. The aircraft engines can be controlled as well as unmanned small spacecrafts can be made to detect presence of harmful and toxic elements in the atmosphere. Many areas of technology are enriched by MEMS. This symposium, I am sure, will result in integrating efforts in these areas and will lead to application oriented R&D in MEMS technology in our country and elsewhere.

I wish the organisers of the symposium all success in their endeavour.

A P J Abdul Kalam

[A P J Abdul Kalam]

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Dr K.Kasturirangan
Chairman, ISRO

October 29, 1996

MESSAGE

I am delighted to learn that, the Society for Photo Optic Instrumentation Engineers (SPIE) is organising a symposium on Smart Materials, Structures and Micro Electro Mechanical Systems (MEMS) at Indian Institute of Science, Bangalore during December 11-14, 1996.

Advancement in the area of smart materials, sensors, actuators and MEMS have made significant contributions to the development of aerospace, marine, bio-medical and civil engineering disciplines. It is very thoughtful on the part of the SPIE to have organised a symposium on this important topic at this juncture. I am sure the symposium will be a useful forum for practicing engineers, researchers and academicians to exchange their views and experiences.

I send my warm greetings to the participants and best wishes to the organisers for the success of the symposium.

(K Kasturirangan)

D.O.No. DG/TS/96-M3

र. अ. माशेलकर

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Oct., 28, 1996

- MESSAGE -

Smart Materials - Twentieth Century Research Marvel

Smart structures and intelligent materials could easily be termed marvels of modern scientific research. Indulging in intellectual explorations to invent need based artefacts has been intrinsic to human nature all through history. The development of smart materials marks man's relentless urge to harness the power of high science and advanced technology to create wealth for wider societal benefit. Characterised by the property to respond to stimuli, smart materials impart a degree of intelligence for self-inspection and adaptiveness to a system or product and enhance its functionality and thereby its value. So much so, once smart materials start replacing existing products and applications, it would be possible to have noiseless and vibrationless gadgets & machinary, infrastructural edifices that combat environmental damages, through smart technology aimed at achieving greater human comfort. The tremendous impact of potential benefits of these materials to diverse industries is thus very promising.

I congratulate the organisers of the first international symposium on Smart Materials, Structures and MEMS under sponsorship of SPIE at Bangalore. I do hope the participants have an indepth exposure to the state-of-the-art developments in the field and the deliberations will motivate dedicated research among the Indian scientists in this vital frontline R&D area. I send my best wishes to the organisers and wish the symposium a very grand success.

(RA MASHELKAR)

Dr.V.K. Aatre
CCR&D (A) &
Distinguished Scientist
Room 136, B-Wing
Sena Bhavan
New Delhi- 110 011

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Shyamal Ghosh
Additional Secretary

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अ० स० पत्र सं०

D.O. No. .....

दिनांक/Dated : ...30.10.1996.....

MESSAGE

I am happy to note that a symposium on Smart Materials, Structures and MEMS is being organised at Bangalore during December 11-14,1996 under the aegis of SPIE - the International Society for Optical Engineering and co-sponsored by DRDO, DST. ISRO, IISc., and DOE.

2. While the ever increasing capabilities of semiconductor process technologies and CAD tools are leading to integration of entire systems on a chip, microelectronics in combination with sensors, actuators, control and communication, is also enabling realisation of Micro Electro Mechanical Systems (MEMS) which usually form an integral part of many smart structures. Smart structures and MEMS offer exciting potential applications in automobile, health care, environment, industrial control and automation, civil and military aviation, consumer goods etc. Besides providing a forum for technical interaction amongst scientists and engineers, I am sure that the deliberations during the symposium would generate a lot of interest among industry, R&D laboratories and academic institutions and provide guidelines for the future activities in this area in India.

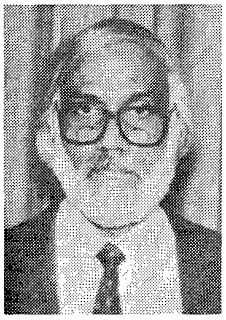
I wish this Symposium all success.

Shyamal Ghosh

(Shyamal Ghosh)

INDIAN INSTITUTE OF SCIENCE
BANGALORE 560 012, INDIA

Professor G. Padmanaban
Director



MESSAGE

Smart materials and MEMS, originally developed for military use, have been finding increased applications in our everyday life. The research and development in smart materials, structures and MEMS at the Institute is an interdisciplinary effort comprising faculty from Aerospace, Electrical Communication and Material Science. The research at the Institute in these areas address many a vital need of some of our national initiatives.

I am extremely happy to learn that the SPIE's 96 International Symposium on Smart Materials, Structures and MEMS is being organised at the Indian Institute of Science, during Dec. 11 - 14, 1996. From the program schedule, I see that a galaxy of eminent scientists from India and abroad have come forward with state-of-the-art contributory and invited papers. The papers cover a wide spectrum of topics and give a panoramic view of the trends in these areas.

I wish the conference the very best.

November 1996

G PADMANABAN

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GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
Department of Science & Technology
Technology Bhavan, New Mehrauli Road, New Delhi-110016

October 29, 1996.

MESSAGE

I am delighted to note that an International Symposium on Smart Materials Structures and MEMs is being organised in India. The scientific and technological importance of this new class of materials needs no introduction. I am sure our scientists and engineers will benefit considerably through active participation in this symposium. My very best wishes for the success of the symposium.

(V.S. Ramamurthy)

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FOREWORD

Man's proclivity for searching newer and newer materials has taken him from 'stone' age through 'metal' age to the present 'silicon' age and ages of smart materials. From smart materials he has now graduated to smart structures and sensors by building in 'intelligence' - usually some form of (digital) signal processing - resulting in 'monitoring' actuating and controlling' systems - all in one 'micro' package. Such and similar array of smart devices combining electrical and mechanical components fabricated with IC batch processing techniques (Micro-electromechanical-systems or MEMS) are finding ever widening use in Aircraft, Automative, Defence, Medical and other consumer applications: applications such as composite materials bridges that heal themselves by filling the cracks as they develop; submarines whose surface soak up obtrusive sonar waves; aircrafts which make themselves invisible to tracking radars; smart wall paper for noise reduction in buildings; aircraft, automobile and ships, airplane wings that stiffen or change the aerofoil shape to adapt to flight stresses, etc. With this new technology of MEMS coupled with radically new design ground rules and new ways for fabrication, technologists are on the threshold of designing and building devices and systems that were never possible before. Consequently, there face entirely new uncharted course in developing mechanical components and systems. This represents a fundamental change in the world of electromechanical engineering. Over the next decade the result will be truly exciting revolution in technology. In military applications 'stealth' or making a 'weapon platform invisible' has special significance. Much of the "stealth" technology that originated in the early 1980s follows research on substances that have been dubbed "intelligent" or "smart". Some of these materials have already crept into everyday life, and for mundane applications like labels for food packaging that change color if the products have been stored at too high a temperature and sunglasses that are indistinguishable from ordinary spectacles in the shade but that darken in dazzling sunlight etc. What makes materials smart is their ability to "react" to the changing environment.

Researchers have already developed artificial muscles and ligaments which when embedded in a host structure, such as the arm of a robot, respond to electrical and thermal signals by bending or flexing. And then there are polymeric gels, which are jellies containing strands of polymers and a melange of charged molecules, or ions. When voltage is applied across the gels, or when the temperature is altered, the ions become implanted in the strands and make the polymers change shape. Along with MEMS and 'wireless communication' systems

these can be used as "snakes" to "sniff" out buried land mines and detonate them. Reduction of noise is another thing which smart materials can efficiently achieve. A logical extension of such coatings, and structure is, besides their known use in Weapons system, is "Smart" Wall Paper" that enables occupants of houses and flats to mask the sound made by noisy neighbors. And then there is the application of smart materials with MEMS as 'smart skins' for reducing drag in aircraft, boats, ships etc. It is clear that this exotic technology can and will find use in very wide spectrum of applications.

SPIE-96 Symposium, co-sponsored by several scientific departments of the Government of India and many Industries, addresses many of the issues and applications of 'Smart' Materials, Smart Structures and MEMS'. The Symposium being held in the celebrains ambience of Bangalore and the Indian Institute of Science brings together, for the first time in India, a large group of polymer scientists, solidstate physicsists, material scientists electrical-mechanical-aeronautical-civil engineers from allover the world. Besides renowned specialists delivering plenary addresses, the symposium has a large number of invited talks from expert rescarders covering various aspects of the 'theme of the symposium'. Abstracts of the papers being presented at the symposium is the main parts of their souvernir and the proceeding will be published by SPIE at a later date. As a appendage to the symposium a small exhibition software and hardware industries has also been arranged.

Clearly smart Materials/MEMS is an emerging technology and Indian Scientists and engineers have just entered this area. There is plenty of research and development work to be done and several questions to be answered: What are the potential applications in India? What are the trade-off issues and cost considerations? What kind of R&D programe should be mouted etc? SPIE-96 symposium would provide a forum for Indian Scientists and technologists to discuss such issues and to brush shoulders with experts elsewhere in the world. This symposium should act as a shot-in-the arm for future work in the area of Smart materials, Smart structures and MEMS.

Dr V.K. Aatre
Chairman
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J.Thani, Tohoku University, Japan.

K.S.Alva, University of South Australia, Australia.

M.Sreenivasan, Massachusetts Inst. Tech., USA.

S.Sastry, University of California, Berkeley, USA.

V.K.Dwivedi, Central Electronics Engr. Res. Inst., Pilani.

W.Seemann, Inst. fur Mechanik, Germany.

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Advertisements

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SHORT TERM COURSE	11th Dec. 1996
SYMPOSIUM	12th Dec. 1996 to 14th Dec. 1996

Short Term Courses

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Date	11th Dec. 1996	
Time	9.00 am - 5.30 pm	
COURSE 2	Room No. 2	JN. Tata Auditorium
Date	11th Dec. 1996	
Time	9.00 am - 5.30 pm	

SYMPOSIUM

12th December 1996	13th December 1996	14th December 1996
INAUGURAL SESSION JN Tata Auditorium	PLENARY SESSION JN Tata Auditorium	PLENARY SESSION JN Tata Autitorium
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Coffee Break 10:40 to 11:00	Session-10 JN Tata Auditorium, Room No.1 11:00 to 1:00 pm	Session-20 JN Tata Auditorium,Room No.1 11:00 to 1:00 pm
Session-1 JN Tata Auditorium, Room No.1 11:00 to 1:00 pm	Lunch Break 1:00 to 2:00 pm	Lunch Break 1:00 to 2:00 pm
Lunch Break 1:00 to 2:00 pm	Session-11 JN Tata Auditorium, Room No.1 2:00 to 3:40 pm	Session-21 JN Tata Auditorium, Room No.1 2:00 to 3:40 pm
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Session-4 JN Tata Auditorium, Room No.2 11:00 to 1:00 pm	Lunch Break 1:00 to 2:00 pm	Lunch Break 1:00 to 2:00 pm
Lunch Break 1:00 to 2:00 pm	Session-14 JN Tata Auditorium, Room No.2 2:00 to 3:40 pm	Session-24 JN Tata Auditorium, Room No.2 2:00 to 3:40 pm
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High Tea Cultural Programme 6:30 to 7:30 pm	Coffee Break 3:40 to 4:00 pm	
	Symposium Banquet at Hotel Ashoka-Bangalore 7:30 pm	

MICRO MACHINING FOR SILICON MICRO ACCELEROMETER

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India

ABSTRACT

Development of silicon micro sensors often require the fabrication of micro mechanical parts (e.g. diaphragm in the case of pressure sensor and a cantilever beam or seismic mass of accelerometer), which are fabricated by etching areas of silicon substrate away selectively to leave behind the desired geometries. Hence the term "micro machining" designates the mechanical purpose of the fabrication process which are used to form these micro mechanical parts. Isotropic and an isotropic etching of silicon together with the various etch stop techniques have been used for fastening micro mechanical parts from silicon and form the basis of "Bulk micro machining" .In another approach called the "Surface Micro machining" the silicon substrate is primarily' used as the mechanical support upon which the mechanical elements are fabricated.

In this paper, the fabrication techniques for realizing silicon micro accelerometer using the above two approaches are presented and the relative merits are compared.

CERAMICS, CERAMIC POLYMER COMPOSITES FOR UNDERWATER APPLICATIONS

T.C.Goel

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ABSTRACT

Lead Zirconium Titanate has been modified by various rare earths like La, Sm, Eu, Gd and Nb. PLZT/Epoxy composites in 1:3 connectively have also been prepared. These materials have been characterized for Dielectric, Piezo - and Pyro electric properties. Several useful compositions, of useful figure of merit have been identified. Hydrophone arrays have been designed, and fabricates using ceramics and Ceramic/Polymer Composites developed in the laboratory. Their characteristics are also reported in this paper.

SMART ANTENNA DEMONSTRATION MODEL

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ABSTRACT

Antenna stabilization for Airborne applications requires very intricate and complicated controls and mechanisms. Taking advantage of the work done in smart structures technology, CABS and IISc are trying to develop a self-stabilizing antenna for use in the radome of an aircraft. As a first step a model is designed with embedded Magnetostrictive Mini Actuators (MMA) in the supports with provision to correct the pitch errors. This includes also the design of a controller with angular displacement feed-back to control the error in the pitch angle. A model will be fabricated with the above design will be validated. After the validation of the design, a 3-D full-fledged stabilized antenna will be attempted.

APPLICATION OF OPTICAL TECHNIQUES IN SMART STRUCTURES - AN OVERVIEW

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ABSTRACT

In recent years exciting developments have taken place in the area of smart structures which are designed to react to their environment by use of integrated sensors and actuators in their body. Such structures can not only monitor the health of their body but also forewarn about the onset of abnormalities in their states thus enabling one to initiate damage and failure control mechanisms

With the advent of lasers, holography, fiber optics, semiconductor opto electronics and infrared thermal imaging, applications of optical methods have increased by leaps and bounds. Integrated Optics technology has further enhanced the capabilities in terms of miniaturization, batch production, economy and reliability. Fiber optic sensors (FOS) are in the forefront in their choice for incorporation into materials and structures made of carbon and glass fiber-reinforced polymer composites.Embedded FOS have been used to monitor cure state of composites, temperature, strain and delamination measurements, and other such applications. A comparison of FOS with micromachined silicon and other micro-sensors is also presented. The main advantages of fiber optic sensors are freedom from EMI, wide bandwidth, compactness, geometric versatility and economy. Specially prepared fibers can withstand high temperature and other harsh environments Besides sensing, fibers can also be used to convey the sensed information to a remote station. Deployment of distributed and array sensors covering extensive structures and geographical locations is also feasible. Many signal processing devices (splitter, combiner, multiplexer, filter, delay line etc.) can also be made of fiber elements thus enabling the realization of an all-fiber measuring system.

SAW BASED TECHNIQUES FOR SMART CHEMICAL SENSING AND IDENTIFICATION

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ABSTRACT

This paper reviews important recent developments in the area of chemical microsensing based on changes occurring in the velocity and attenuation of the surface-acoustic-waves (SAW) under chemical transduction. Most SAW sensors basically consist of a SAW delay line or resonator coated with a chemical selective absorptive film. In order to read out the chemical information these devices are used in the feedback loop of an oscillator circuit where changes in the film properties (mass and visco elasticity) are translated into shifts in the frequency and gain. Besides, some new smart sensor systems have been developed which are based on other types of SAW devices like chemical selective ID-tags and spread spectrum signal generation and correlation filters. In them, the read out and address functions are realised by RF interrogation of specific codes. In order to improve selectivity, sensitivity and reliability the SAW sensor arrays are employed to collect information about several species simultaneously, and data is analysed using advanced methods like pattern recognition algorithms for identification and quantitative estimation. In this paper, emphasis is laid on the high sensitivity gas and vapor sensors for real-time monitoring in hostile chemical environments such as process control in hazardous chemical industries, environmental protection, explosive detection and drug abuse. In addition, different approaches to develop monolithic integrable SAW sensors are also briefly summarized.

MICRO FLOW METER INTEGRATED WITH AN OPTICAL SENSOR

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ABSTRACT

Conventional hot wire flow meter made of metal filament is usually bulky and power consuming. Presently metal wire has been replaced by Polysilicon bridge by using micromachining technique with conventional silicon processing technology. The flow of the gas can be measured by putting the silicon wire in the gas stream with a constant heating power and measure the temperature of the wire as function of the gas flow or to keep the wires at a constant temperature and measure the power required to do so. Although the system is quite sensitive but due to the high thermal conductivity of silicon, an appreciable part of heating power is still lost in the substrate. The thermal response time is also in millisecond.

To overcome these two difficulties a new type of micro flow meter is designed. In this flow meter instead of a bridge, a air turbine with a radius of 2000 μm is generated in the silicon chip by using bulk micromachining technique.

SILICON ANISOTROPIC ETCHING FOR FABRICATING DEEP VERTICAL WALLED MICRO CHANNELS

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ABSTRACT

KOH, water and isopropanol based etchants have been used to etch silicon for fabricating micro electromechanical components and structures for various applications. For microchannels, (110) orientation silicon wafer is used. Proper orientation of the pattern to be etched is needed to be aligned with reference to the standard flat provided in the commercial wafer. Many a times, the orientation of the flat may not be accurate and therefore Quality of the channel walls and the bottom of the trench may get affected adversely. A method has been developed, where proper orientation is experimentally determined on the given wafer for pattern delineation. Besides this, side etching poses problem especially during fabrication of deep microchannels in excess of 200μm. Here, Quality of the masking dielectric layer has been noted to be of importance. A SiO_2- Si_3N_4 - SiO_2 combination has been developed for etching 250-300μm deep vertical walled microchannels in (110) silicon. Very smooth walls and bottom of the trenches have been obtained after controlling the etchant composition, temperature and careful orientation of the masking pattern. Process details will be presented with experimental results achieved in this connection.

MICROMACHINED ACOUSTIC INTENSITY SENSOR

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Concordia University

ABSTRACT

Measurement of acoustic intensity provides information not only on sound pressure level at the point but on the direction of sound prorogation also. Acoustic intensity calculation needs the pressure information and pressure gradient information at a point. Pressure gradient at a point is obtained using pressure measurements from two closely spaced microphones and employing finite difference technique.

Presently, condenser microphones placed at a small distance are used for acoustic intensity measurements. These transducers require a preamplifier and a signal processing unit making the assembly cumbersome and possibly interfering with the sound field itself. Micromachined sensors are ideal under these circumstances in view of their miniature size, low cost high reliability and the convenience of having the signal processing circuitry in the same microchip close to the sensor.

The present study is on the acoustic intensity sensor by micromachining.

MICRO MACHINED POLYSILICON TORSION MIRRORS FOR AN ELECTROSTATIC OPTICAL SWITCH IN A FREE SPACE

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ABSTRACT

Though the switching response of opto-mechanical switch is not as fast as that of the waveguide switch based on electro-optical effects, they are widely used in some applications,for example, cross-connection of the, optical fibers and optical re-routing in measurement instruments. For these applications, large attenuation ratio and small crosstalk of opto-mechanical switches are more attractive specifications rather than high speed. Furthermore, opto-mechanical switches based on the reflection of mirrors, for instance, have favorable characteristics such as independence of wavelength and polarization. However, most of the conventional mechanical switches are not suitable for miniaturization, integration, or mass-production because they are made by assembling of macro-machined work pieces. Micromachining is, therefore, expected to give a solution to this problem.

We propose a new configuration of free-space optical switching matrix by using electrostatically operated micro mirrors. By choosing an appropriate set of mirrors we can realize several switching states.

MAGNETICALLY DRIVEN SELF-MOVING MICROACTUATORS

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ABSTRACT

Micro-magnetic actuators are featured with large deflection and force available in a 0.1mm-10mm size as well as their wireless power supply capability, robustness and low electric-impedance driving. New self-moving (-flying, -swimming, -running) microactuators are demonstrated in this paper taking advantage of the wireless power supply capability of the micro-magnetic actuators. The actuation force is generated by the interaction between a given ac external magnetic field and the magnetic material used for microactuators.

A small flying actuator has two hard magnetic film wings, two polyimide film wings connected in series to magnetic wings, and a soft magnetic wire as an attitude control body. This actuator imitates the flying mechanism of small insects which feel low Reynolds number in air.

A spiral-type swimming microactuator is composed of a 1 mm^3 cubic SmCo magnet and a spiral wire connected to a side of the magnet.

A magnetostrictive bimorph cantilever is made of the amorphous TbFe thin film having positive magnetostriction and the amorphous SmFe thin film having negative magnetostriction, deposited on the opposite sides of a polyimide film substrate. A self running microactuator is possible using this mechanism.

CAD OF MEMS GETTING OUT TO THE INDUSTRY

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ABSTRACT

Besides foundry facilities, Computer-Aided Design (CAD) tools are also required to move Microsystems from research prototypes to an industrial market. Currently available CAD tools need extensions before they can be used for the automated design of micromachined devices. This paper describes the extension of Mentor Framework to Microsystem Technology (MST). The tool allow to a designer a continuous design flow from the schematic level to the layout level including a mixed-signal, multi-level simulation by the means of a fully characterized set of device level microsystem components. Today, the environment supports the CMOS compatible bulk micromachining but is open to other microsystem technologies and includes technology independent layout generators for structures such as bridges, cantilevers, membranes and generic structures.

1-10 GHz GaAs MMIC DISTRIBUTED AMPLIFIER

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GAETEC Project
Hyderabad, INDIA.

ABSTRACT

A monolithic GaAs travelling-wave amplifier with 8.5 dB gain and +/- 0.5 dB gain flatness in 1 - 10 GHz frequency range has been designed. Travelling-wave topology was chosen to design a decade bandwidth amplifier in 1-10 GHz band as this topology offers ultra wideband performance with flat gain response and low input and output VSWRs with moderate noise figure and power outputs. Distributed amplifiers offer very high gain bandwidth products as these are not matched amplifiers and therefore not subject to Fano's bandwidth limit. In this approach GaAs MESFETs periodically load input and output microstrip lines and provide the coupling between them with proper phase through their trans-conductance. The FET gate and drain capacitances are combined with inductors to form gate and drain lumped element artificial transmission lines and terminated by gate, drain line impedances. The design is based on 0.7μm GaAs MESFET on 200μm GaAs substrate without via holes. To obtain the required gain bandwidth product a 240μm gate width GaAs MESFET was chosen. Eight numbers of such FETs are used to realize the circuit with a trade off between gain and noise figure, and also to ensure moderate output power. A novel layout has been implemented to bring all the FET sources near the chip periphery for proper RF grounding. The gate and drain transmission lines are realized with the two different interconnect metal lines available in the technology. This technique provides the inherent isolation between gate and drain transmission lines as they are separated by two dielectric layers. Using the above techniques the layout has been generated within a chip size of 2.75 mm x 1.43 mm. Reverse simulation (LVS) from the layout ensures the design specifications.

CAD OF 6 BIT L-BAND PROGRAMMABLE MMIC PHASE SHIFTER

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Vignyana Kancha, Hyderbad-69.

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ABSTRACT

The 6 bit programmable phase shifter circuit has been designed in the frequency range 1.15 to 1.75 GHz. The phase shifter circuit consists of 6 digital phase bits corresponding to differential phase shifts of 5.625, 11.25, 22.5, 45, 90 and 180 degree cascaded in series. This arrangement provides 64 phase states between 0 and 360 degree in the steps of 5.625 degree. The differential phase of each bit is achieved through the switching between high pass and low pass filter using switching MESFETs. The 'ON' and 'OFF' states of switching MESFETs are used to make a single circuit perform the function of high pass and low pass filter. The component structures of high pass/low pass filter are realized as lumped elements rather than distributed elements to effectively reduce the chip size. The parasitic capacitance of MESFET is utilized to form a part of component elements of high pass/low pass filter circuit of each phase bit to ensure wide band performance. Each phase bit has been designed using suitable filter structure with optimum number of elements for very low phase error, low insertion loss and good return loss to ensure the overall performance after cascading. The phase shifter designed will provide RMS phase error of less than 3.9 degree and return loss better than 13.3 dB over all 64 states in the frequency range 1.15 to 1.75 GHz. The switching device used is 0.7μm gate length ion implanted MESFET. The entire circuit of the phase shifter is laid out as two chips (size : 6mm X 3.2mm and 7mm X 3.2mm) to keep the aspect ratio less than 3:1 which improves the yield.

ELECTRICAL AND STRUCTURAL CHARACTERIZATION OF THIN FILMS OF LA-MODIFIED PZT PREPARED BY SOL-GEL TECHNIQUE

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ABSTRACT

Ferroelectric films of composition $Pb_{1-x}La_x (Zr_y Ti_{1-y})O_3$ (PLZT) viz., 8/65/35, 15/40/60 and 18/30/70 have been prepared on fused silica and platinum substrates using a methoxyethanol based sol-gel process. After multiple coating, these films were heat treated at different temperatures. While as deposited films were amorphous and films sintered at 400°C were amorphous, crystallinity was achieved on sintering the films at 600°C. A thin film of $PbTiO_3$ was deposited on the substrate prior to depositing PLZT films to enhance the crystallinity and tetragonal nature of the PLZT films. Results of scanning electron microscopy support the evidence from X-ray studies. Studies have been performed to understand the temperature and frequency dependence of dielectric permittivity and dielectric loss in these films. The dielectric permittivity is of the order 200 - 400 for the three compositions and tan_ is of the order of 0.01 - 0.05. The crystalline films showed D-E hysteresis, with slightly higher values of coercive field, compared with those of sintered bodies. Amorphous films exhibit higher optical transparency and lower dielectric permittivity. Our experimental results suggest that PLZT films prepared by this technique could find useful applications in nonvolatile memories, DRAMs and storage capacitor dielectrics.

PZT CERAMICS MODIFIED BY RARE EARTHS AS SUITABLE CANDIDATES FOR THERMAL IR SENSORS

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ABSTRACT

The paper reports the structural, dielectric and pyroelectric properties of PZT ceramics modified by 5% rare earths i.e. La^{3+}, Ce^{3+}, Nd^{3+}, Sm^{3+}, Eu^{3+}, and Gd^{3+}. Out of these PLZT and PGZT were found in rhombohedral phase, while PCeZT, PNZT, PSZT and PEZT were in tetragonal phase. The lattice volume decreases as rare earths ionic radii decreases except PEZT and PGZT. Dielectric constant is found to increase with temperature but decreases with frequencies. The value of tan δ, however, decreases upto 80°C and than increases slightly. The pyrocurrents (p) as well as pyrocoefficients (pi) increase with temperature upto 50°C and than remains constant upto 80°C. Above 80°C (p and Pi) increase linearly with temperature. The pyro coefficient(pi) and figures of merit of these ceramics are comparable to other thermal IR sensor.

The preparation of these ceramics is simple,inexpensive and properties can be tailored according to the design of the sensors. The results of the studies have shown that these ceramics would be very useful for the development of thermal IR sensors.

OPTICALLY NON-LINEAR POLYMER : CERAMIC ULTRA STRUCTURE COMPOSITES : PREPARATION AND CHARACTERIZATION

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Indian Institute of Technology, New Delhi-110016, India.

*Applied Optics Laboratory

ABSTRACT

Transparent Polyamide:$LiNbO_3$ and Polyamide : $BaTiO_3$ films were prepared by insitu polymerisation of PI and gelation of respective alkoxide sols of the ceramics. These films were characterised structurally by X-ray and SEM. The X- ray diffractograms clearly indicates the presence of crystalline ceramic phase in these films. The optical transmission spectra shows about 80% transmission in the visible range. SEM micrographs shows the presence of ceramics clusters in the polymeric matrix. Moreover the crystallites are distributed in an orderly fashion in these clusters. The dielectric constant at room temperature was found to be about 6 and 10 respectively for $LiNbO_3$ and $BaTiO_3$ composite films. Dielectric loss is very low. Optical phase conjugation using degenerate four wave mixing technique has been observed in PI:LiNbO3 film, while hologram was recorded and reconstructed by two wave mixing in the transmission grating mode.

A NEW TECHNIQUE FOR PIEZO STRAIN CHARACTERIZATION OF POLYVINYLEDENE FLUORIDE SENSOR THIN FILMS

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ABSTRACT

Polyvinyledene Fluoride is very important piezo Pyro and ferroelectric polymer for sensor and actuator applications. Measurement of their thin film thermal piezoelectric and spontaneous strain can be very useful data for their device application. A new technique developed in our laboratory to measure precisely strain of any of above origin with a precision of 10^{-7} cm. has been devised and presented in this work. The technique is based on two terminal capacitance measurement where the involved stain is directly measured in terms of capacitance change ($\Delta C \simeq 0.1$pF). Here the spaces of the capacitor plates are the thin films of samples on which above strains are to be characterized. Such thin film characterization of strain in thin film form of the material is useful since bulk and thin film properties differ and in very many sensor/actuator and transducer application the thin film devices are required to be used at number of places.

EFFECT OF PRESSURE IN PIEZO-ELECTRIC COEFFICIENT OF SENSOR MATERIAL PVF_2

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Pt.Ravishankar Shukla University, Raipur (M.P).

ABSTRACT

The Polymer PVF_2 are 40 to 60% crystalline in one of their polymorphic α, β or γ form and are technologically important material for their useful piezo electric, pyroelecric and ferroelectric property with lot of device applications in transducers sensors and actuators. The crystallinity has important role to play in their application that is affected by poling and stretching that leads to orientation of polymer chains along with conversion to crystalline β phase confirmation.

We are to present experimental facts of mutual dependence of piezoelectric and pyroelectric characteristics when the device material has to be cycled at different temperatures and pressures. The PVF_2 and its devices being both piezo and pyroelectric has to depend very much on this interdependence and such characterization becomes important.

Our studies reveal that PVF_2 films subjected to different pressure lead to pyro-coefficient variation with temperature differently.

A NEW APPROACH TO ACTIVE SOUND ABSORPTION FOR TUBE RECIPROCITY CALIBRATION OF TRANSDUCERS

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ABSTRACT

A new simple approach to active sound absorption is presented for the tube reciprocity calibration of electro-acoustic transducers. In the tube reciprocity method, active sound absorption is used to create a region within the tube in which waves travelling in only one direction are present. In the approach widely used at present, the magnitude and phase of the voltage applied to the absorber are manually adjusted and the outputs from sensors placed at various positions along the length of the tube are used to determine if the desired condition has been achieved. In the present approach, a model of the sound absorber is used to determine the voltage to be applied to the absorber. The active absorber used here consists effectively of a single layer - a piezoceramic disk with a thin waterproof coating. First, the absorber is used as a sensor and when it is excited by a harmonic acoustic wave steady-state open circuit voltage generated by it is measured. When the same acoustic wave is incident upon it the second time, a voltage is applied to the disk such that there is no reflected wave. The voltage to be applied is determined by using a three port distributed parameter model of the disk. The model is obtained by using the plane strain approximation.

LIQUID CRYSTALLINE POLY (ESTER-AMIDE)S CONTAINING CHIRAL GROUPS FOR SECOND HARMONIC GENERATION

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ABSTRACT

Smart materials which can behave intelligently as demanded by the situations are finding enormous applications in various fields of science and technology. But the development of such new materials which could survive the test of time has been a difficult task owing to their lack of stability under thermal and photochemical conditions.

Now we herein report the synthesis, characterization and optical properties of a new poly (ester-amide) which contains chiral moiety as one of the building blocks. The poly (ester-amide) was obtained by the condensation of bis-(2-chloroformyl-4-nitro) phenyl terephthalamide with poly (ethylene glycol) and 2, 4 : 3, 6 dianhydro-D-sorbitol. A series of such poly (ester-amide)s were prepared by changing the ratios of PEG and isosorbide. The polymers were characterized by spectral and thermal techniques.

PRESSURE-ASSISTED FUSION BONDING OF SILICON WAFERS

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ABSTRACT

Silicon-to-silicon bonding with an intermediate oxide layer is an important aspect of the fabrication of microsensors and actuators. So far, the bonding techniques reported in literature can be broadly classified into two groups, viz. anodic or field assisted bonding [1-3] and fusion bonding [4-6]. Of these, anodic bonding process requires the application of an electric field at high temperature (800°C-950°C) involving complex fixturing and also the problem of oxide breakdown. On the other hand, fusion bonding requires ultra clean wafer surfaces and consequently stringent processing conditions.

In this work, we have developed a novel, two step, pressure-assisted fusion bonding process which has proved to be extremely successful in bonding two silicon wafers. Moreover, as this process does not require a very high degree of surface cleanliness and flatness, it is more suitable for practical applications.

NONLINEAR DYNAMIC ANALYSIS OF LAMINATED ANISOTROPIC PLATES/SHELLS WITH PIEZOELECTRIC SENSORS AND ACTUATORS

M.Umapathi,S.S.Gupta,B.P.Patel and M.Ganapathi

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ABSTRACT

A finite element formulation is presented for vibration control of a laminated plates/shells with piezoelectric sensors/actuators. The element used here is based on first-order shear deformation theory with induced strain actuation. The governing equations are obtained using Lagrange equation of motion. The geometric nonlinearity based on Von Karman's assumptions and structural damping in the form of Rayleigh damping are introduced in the present model. The charges produced on the sensor elements are obtained directly from the piezoelectric equations. The piezoelectric sensors and actuators are distributed over the structure. Depending on the type of controller, the piezoelectric sensor voltage is assumed to be dependent either on the strain or strain rates over the sensor area. The actuators are assumed to induce control moments on the laminate. The formulation also takes into account of the flexibility of the sensors/actuators along with the laminates.

Eight-noded element with five nodal degrees of freedom for structural modeling is considered for the present analysis. The model developed here is validated against available results on bimorph beam. The time response history is obtained using unconditionally stable Newmark method coupled with Newton Raphson technique. Furthermore, an attempt is also made to design multi-input multi-output controller to simultaneously annul the displacements over the whole structure.

DEVELOPMENT OF POLYPYRROLE BASED CONDUCTING MEMBRANE

Ramadhar Singh

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ABSTRACT

Polypyrrole based conducting membranes have been prepared by chemical oxidation method. Variation of surface resistance of the membranes as a function of polymerization temperature has been examined. Surface structure of the membranes has also been examined by scanning electron microscopy. Fourier transform infrared (FTIR) spectrum confirms the synthesis of polypyrrole based conducting membranes. Effect of annealing temperature on the surface structure of the membrane has been studied. Differential scanning calorimetric study and thermal gravimetric analysis provide the evidence that the membrane can be safely annealed up to 373°K. The processing conditions of the membrane has been optimized as functions of annealing and polymerization temperature. These conducting membranes have been tested for poliomyelitis virus retention capacity and it has been found that the polypyrrole based membrane captures almost 100% poliomyelitis viruses from water.

NATURAL RUBBER BASED CHIRAL POLYESTERS AS ACOUSTIC DAMPING MATERIALS: SYNTHESIS AND CHARACTERISATION.

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ABSTRACT

The viscoelastic passive damping technology has proved to be one of the most effective methods to significantly improve the dynamic and acoustic performance of materials. In this context development of new viscoelastic damping materials are important. With this view inherently damping natural rubber based chiral polyesters were developed and characterised. The damping property of rubber is expected to be further improved by viscoelastic nature of the material and also, the presence of chiral moiety can produce additional mechanisms of attenuation as a result of nonlinear effects of wave propagation. New damping materials were developed starting from hydroxyl terminated liquid natural rubber prepared by photodepolymerisation of coagulated natural rubber latex by reacting with 1,4:3,6-dianhyro-D-sorbitol and terephthaloyl chloride/ (bis-2-chloroformyl,4-nitrophenyl) terephthalamide. The copolyesters containing cycloaliphatic and linear chain aliphatic ester groups were characterized by spectral and thermal techniques. Inherent viscosities were measured and retention of optical activity was checked by polarimetry. Differential scanning calorimetry and thermogravimetric studies were used to assess their thermal performance. Curing behavior was also studied. The damping performance was studied using DMA technique and was found to be superior compared to starting natural rubber.

DEVELOPMENT OF SMART PIEZOCOMPOSITE FOR UNDERWATER DETECTION SYSTEMS

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ABSTRACT

Highly anisotropic lead titanate (PT) ceramic powder was synthesized under controlled sintering conditions. The sintered powder was crushed and ballmilled to yield mean particle size of about 1 micron. Piezocomposites were fabricated using this ceramic powder as filler material homogeneously dispersed in passive chloroprene rubber matrix. Good quality composites could be obtained by choosing proper curing time and temperature. The dielectric and piezoelectric properties were measured as a function of frequency and temperature. A prototype hydrophone was made by enclosing a cylindrical section of the composite with an acoustically transparent neoprene rubber boot. Acoustical evaluation of the hydrophone was accomplished by the comparison calibration method using a calibrated projector and hydrophone. The composite hydrophone exhibited sensitivity close to -200dB re lV/mPa which is of immense utility in designing various underwater detection systems.

BIREFRINGENCE IN PM FIBERS USING THE BEAT-LENGTH MEASUREMENT TECHNIQUE

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ABSTRACT

High birefringence property in optical fibers introduced a great number of fiber structures. Specially designed polarization maintaining (PM) fibers such as low loss monomode polarization fibers and other functional fibers appeared in the literature which have already been made commercially available. PM fibers are, indeed, the subject of intensive research because of their versatile applications in coherent optical communications and fiber optic sensors. Experiments have shown that fibers with asymmetric intrinsic thermal stress, that results in high birefringence, have the most promising directional properties. In spite of the promising characteristics of such PM fibers, the detailed analysis of their optical properties has not been fulfilled yet. The aim of this paper is focussed on the investigation of the modal birefringence property of the fundamental type of elliptical core PM fiber with the help of beat length measurement technique.

SYNTHESIS AND CHARACTERISATION OF COMPOSITES OF FINE MAGNETIC PARTICLES WITH COPOLYMER OF ANILINE

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ABSTRACT

When materials possessing long range magnetic order (e.g.ferromagnetism, antiferromagnetism, ferrimagnetism) are reduced in size they can show unique properties as compared with bulk materials. One of the ways to reduce the size of the ordered magnetic regions is to isolate them inside non-magnetic species. Though there are various methods of doing it but chemical is more effective as it has the following attractive features : i)tailored synthesis by assembly of atomic or molecular precursors, ii) controlled stoichiometry, iii) mixing of constituent phases at molecular level and iv) cost effective production of bulk quantities of materials. In the present paper we report the in-situ synthesis and characterisation of composites of fine magnetic particles with copolymer of aniline.

GAS SENSOR DEVELOPMENT AT B.A.R.C.

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ABSTRACT

The detection/measurement of gas concentration at low levels is important for process control, environmental monitoring, industrial safety etc. among many other applications. Consequently, highly sensitive, conveniently usable, low power solid state devices are being developed and gaining immense importance in various fields. The research on metal oxide thin film based gas sensors has been carried out world over to achieve these objectives. At B.A.R.C., our Division has been carrying out R & D in the area of gas sensors for last four years largely with the purpose of developing highly sensitive devices with fast response and recovery times for use in industrial environment.

The present paper discusses basic physical processes responsible for gas detection through ac/dc conductivity modulation of the sensor film due to film-gas interaction. Some of the important aspects of these devices for hazardous and toxic gases will be discussed. Specific attention will be devoted to the development work we have done on H_2S gas sensors having sub-ppm sensitivity and rapid response. Currently developed one kind of H_2S sensor has a response time of less than a minute and full recovery of the film resistance takes less than five minutes while the other type of sensor can detect this gas at levels less than 500 ppb present in the environment. A comparison of response and recovery times of our sensor and that of a commercially available sensor is depicted in the figure. Development work being currently carried out on other gas sensors will also be outlined.

CAD OF 0.1 GHZ TO 10 GHZ GaAs MMIC SPST SWITCH

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ABSTRACT

SPST switches perform one of the system functions of turning RF power'ON'or 'OFF'. GaAs MMIC SPST switches have faster switching speed, consume lesser DC power and are smaller in size compared to PIN diode switches. MESFET which is used as switching element in SPST switch acts like a very low value resistor in the 'ON' state and as a capacitor in the 'OFF' state. The 'OFF' state parasitic capacitance of MESFETs degrade the high frequency performance of SPST switch in terms of insertion loss and isolation. The insertion loss is improved by treating SPST switch as a 50Ω artificial transmission line with incorporation of inductor in series arm and the capacitance of MESFET in the shunt arm. High isolation is ensured by the lower value of 'ON' resistance of MESFET in shunt arm. Also good return loss is achieved by paralleling a 50Ω resistor with capacitance of MESFET in series arm. The absence of DC blocking capacitors and replacement of large value bias chokes with 5KΩ resistors effectively improved the performance of SPST switch at low frequency and also reduced the chip size. All the element parasitic are incorporated in the design program to ensure realistic performance. The predicted response of the SPST switch using 'Libra' software package provides an insertion loss less than 2 dB, isolation more than 40 dB and return loss better than 18dB over a frequency range of 0.1 GHz to 10 GHz. The return loss has been ensured not only in the low insertion loss state but also in high isolation state. The fabrication process involves 8 layer mask. Contact lithography with deep UV defines circuit pattern by exposing photo resists in the areas determined by each mask. The switching devices used are 0.7μm ion implanted MESFETs. Low loss top metal is used for spiral inductors to minimise insertion loss. Silicon nitride MIM capacitors are used for RF by passing. The ion implanted resistor is used at MESFET gate for isolating RF & DC. The overall chip dimension is 2.2mm X 1.7mm.

POLYMERS WITH SECOND ORDER NON-LINEAR OPTICAL PROPERTIES : SYNTHESIS AND CHARACTERIZATION

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ABSTRACT

One of the formidable challenges in present-day chemical synthesis is the construction of multimolecular assemblies with tailor-made properties. This is achieved by engineering interactions, spatial relationship between preselected constituent molecular building blocks. When molecules with non-linear optical behaviour are incorporated into glassy polymeric structures, additional attractions of supramolecular organization including improved mechanical/ dimensional stability and optical transparency can be achieved. Such materials containing natural rubber (or modified natural rubber) are expected to show better performance.

The present work involves the synthesis and characterization of a series of poly (ester-amide)s containing a chiral building block. The poly (ester-amide)s were prepared from bis-(2-chloroformyl-4-nitro)phenylterephthalamide, hydroxy terminated liquid natural rubber and 2, 4 : 3, 6 dianhydro-D-sorbitol (isosorbide). A series of poly (ester-amide)s were prepared by changing the molar proportions of the comonomers. The characterization of the polymers were done by spectral and thermo-mechanical techniques. Optical purity was ascertained by using a polarimeter. The incorporation of vulcanizable liquid natural rubber building block offers additional attractive feature together with the non-linear performance due to the chiral isosorbide building block. The non-linear optical behavior is measured as a function of the relative proportion of the isosorbide and HTNR building blocks.

NON-LINEAR OPTICAL PROPERTIES OF COPOLYESTERS CONTAINING AZOBENZENE FUNCTIONALITY AND CHIRAL GROUPS

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ABSTRACT

The development of organic and polymeric materials containing donor-acceptor and/or chiral groups has been a subject of much interest recently. They find wide applications in several fields of science and technology. The synthesis and characterization of a series of new copolyesters containing azo mesogenic groups and chiral groups are reported. The polyesters were prepared by the condensation of bis(4-hydroxyphenyl)azo-2,2'-dinitrodiphenylmethane, terephthaloyl chloride and 2, 4 : 3, 6 dianhydro-D-sorbitol (isosorbide). The polymers were characterized by spectral and thermal techniques. Optical purity was checked by polarimetry and found to retain more than 95% optical activity. DMA studies revealed the non-linear behavior towards mechanical vibrations. Exposure to a laser source established the non-linear optical properties. High values of second order non-linear susceptibilities were recorded as a function of the molar proportion of isosorbide units.

ACTIVE VIBRATION CONTROL OF BEAMS AND PLATES WITH PIEZOELECTRIC MATERIALS

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ABSTRACT

The problem of active control of vibration of beams and plates using piezoelectric materials is considered. Two approaches to active control, coupled control and independent control are considered. In coupled control all the vibration modes are controlled simultaneously. In independent control, a selected number of vibration modes are controlled by equal number of actuators. The controls are derived independently for each mode. Two piezoelectric materials PZT and PVDF are used in the study. The finite element method is used for the dynamic analysis. Only the bending vibrations are considered. While in coupled control the piezoelectric materials are used both as actuators and sensors, in independent control they are used only as actuators.

MICRO AIR TURBINE-BY MICROMACHINING OF SILICON

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ABSTRACT

Fabrication of micro-mechanical components is the basic need for the construction of micro-mechanical systems. The development of silicon micromachining by anisotropic and isotropic etching made it possible to make micro-components and devices which could not be achieved by conventional machining. Once these micro-structures are free from their silicon substrates, these can be used to build a wide array of micro-mechanical systems. Moreover, the use of silicon processing technology makes possible the fabrication and integration of sensors, actuators, and control circuitry on the same chip.

In this paper, the fabrication technique for realising a micro air-turbine by using "Bulk Micro machining" of silicon is presented. The technique provides the simple and better control to fabricate the components for this turbine without employing expensive equipments such as LPCVD reactor, reactive ion etcher or Ion beam milling system etc. Further work is in progress to integrate the turbine with an optical sensor and control electronics on the same chip.

GENERATION OF MICROSTRUCTURES IN SILICON FOR MEMS APPLICATION

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ABSTRACT

Excellent mechanical properties of silicon together with the advantage of fabrication of the IC circuitry on the same chip make it a very viable material for sensors. Thin membranes generated in crystalline silicon are an integral part of many micro electromechanical systems. There are various techniques used for generation of micro structures in silicon for fabrication of sensors and actuators for applications in MEMS technology. These involves isotropic and anisotropic etching using various chemical etchants. In this paper, we present a new technique based on dopent dependent selective anodization to make thin membranes of silicon isolated by porous silicon. This technique as the advantage that the device geometry can be defined and thickness of silicon can be controlled more accurately.

EFFECT OF BORON ON STRUCTURE AND PROPERTIES OF CU-AL-NI SHAPE MEMORY ALLOYS

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ABSTRACT

Copper- 13Aluminium - 4Nickel shape memory alloy is the most promising of the varieties of alloys presently available. The alloy exhibits high strain recovery and better resistance to thermal degradation. However, the polycrystalline Cu-Al-Ni alloys suffer from brittleness imposed by the inherently large grain size. An attempt was made to improve the ductility by microadditions of grain refining elements. It was established that addition of 0.05% Boron to the base alloy was effective in reducing the grain size from 780 μm to 130 μm. The grain refinement resulted in suppressing the tendency of the alloy to intergranular fracture and thus substantially increasing the yield strength, tensile strength and fracture strain. The effectiveness of boron was attributed to the formation of AlB_{12} , which effectively prevents grain growth at solution treatment temperatures upto 850°C beyond which its effectiveness was found to decrease. Aging the solution treated alloy at temperatures upto 300°C resulted in significant increase in strength and decrease in ductility because of the precipitation of γ_2 though the benefits of grain refinement are evident in the aged condition.

OPTIMISATION OF STRESS IN LPCVD POLYSILICON FILMS FOR MEMS APPLICATION

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ABSTRACT

Polycrystalline silicon as a mechanical material is being extensively used in the development of microsensors and actuators using surface micromachining technology. The performance and control of the dimensions of these devices are dependent on the residual stress, and stress gradient in the film. These parameters in turn are governed by the processing conditions of the polysilicon. Low pressure chemical vapour deposition (LPCVD) technique is widely used for polysilicon deposition micromechanical and CMOS devices. The process parameters of polysilicon are required to be optimized not only to achieve thin film with minimum stress and stress gradient but also to facilitate merger of the micromachining technology with the well established CMOS technology for realization of MEMS.

In this paper, the effect of polysilicon process parameters such as pressure, temperature, and silane flow rate on the mechanical properties of polysilicon has been studied. The influence of doping, and annealing on average residual stress and stress gradient in the film has also been investigated with a view to develop optimized process for MEMS applications. Various three dimensional structures have been fabricated for measurement of these mechanical parameters.

The effect of the process parameters on the stress measured has been discussed.

VIBRATION CONTROL OF FLEXIBLE BEAM THROUGH SMART STRUCTURE CONCEPT IN THE FIELD OF SMART STRUCTURES AND SYSTEMS.

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ABSTRACT

Active control has become important in structural systems as an efficient tool for vibration suppression. A cantilever beam has been choosen as a flexible structure. The entire structure (Beam with sensors and actuators) is modeled by FEM by using two different elements. A special beam elements, which includes the sensor and actuator dynamics has been developed. This finite element is used to model the regions where piezo electrics are bonded and the rest of the structure is modeled with the regular elements. Since much of the flexible energy is contained by the first few modes, controller is designed to suppress only the first two modes. The state space-model of the system is obtained by appropriate method from the FEM model. The significant structural vibrations have been suppressed by using state feedback and optimal output feedback control laws. The optimal sensor, actuator location for controlling the first two modes has been done.

STUDY OF CAPACITANCE - VOLTAGE CHARACTERISTICS OF ELECTROCHEMICAL CELL FOR BULK SILICON MICROMACHINING

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ABSTRACT

Anisotropic etchants are being widely used for micromachining of single crystal silicon to develop different kinds of sensors and actuators. The increasing miniaturization of these devices demands precise control of the dimensions of their basic elements such as diaphragms, cantilever beams, bridges, suspended masses etc. In the fabrication of the microstructure, therefore, electrochemical etch stop at reverse biased p-n junction or at heavily doped P^+ layer is employed. The p-n junction etch stop technique has an edge over the other due to its adaptability to standard CMOS process with no side effects such as stresses. The technique has evolved from a two electrode system (working and counter electrodes) to four electrode (the other two being standard calomel electrode and one additional working electrode). The biasing potential of the p-n junction is determined from I-V characteristics to achieve selectivity in fabricating microstructures. Though, the technique is well established, the etched dimensions of the structures and the surface texture vary from system to system.

In the present paper we have analyzed capacitance - voltage characteristics to investigate the impact of the space charge region formed in the silicon and thin electric layers of the etchant at the interface on the passivation potential and surface texture. The characteristics have been drawn in an electrochemical cell having KOH as an electrolyte with two and three electrode systems.

GLASS TO SILICON ANODIC BONDING FOR LASER PACKAGING APPLICATIONS

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ABSTRACT

Glass to silicon anodic bonding is a well known process extensively used in the fabrication of several types of microelectromechanical components and sensors. Pyrex glass of appropriate composition can be bonded to silicon by applying bias at elevated temperature. Ionic movement due to applied bias at elevated temperature leads to strong bond. In the fabrication of silicon microchannel based heatsink for laser packaging, a good bonding between chilled water manifold made out of 7740 pyrex glass and silicon wafer containing large number of fine width (50 μm) microchannels over relatively larger area (6mm x 6mm) is needed to be developed. Proper surface preparation of the glass manifold, before and after ultrasonic machining of grooves and water inlet/outlet openings, is critical. Cleaning of microchannel containing surface along with the flatness of the microchannel top is another aspect to be seen carefully for proper mechanical strength. By optimising these process steps, good quality bonded silicon microchannel heatsink structures have been fabricated for laser source development.

Processing details and their influence on the quality of bond will be presented with experimental results.

STUDY ON PRODUCTION OF HIGH SURFACE FINISH BY MAGNETIC ABRASIVE MACHINING

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ABSTRACT

Experimental research has been conducted into the effect of various parameters which are influencing the improvement of surface roughness. The purpose of this paper is to provide a basic understanding of the fundamentals and uses of magnetic abrasive machining and how it can be applied to the fabrication of optical components used in space programme.

Magnetic field - assisted machining using magnetic abrasive particles is one such non conventional machining technology in which the cutting force is controlled by the magnetic field. Finish machining is essentially accomplished without the need for designing expensive, rigid, vibration free and error free machine tools by incorporating the magnetic machining elements necessary into the existing conventional machine tools there by minimising the cost of new equipment. The process can thus very effective and economical. As a result, the surface roughness was reduced to 0.1μm Ra over the entire surface from the initial surface finish of 0.5μmRa.

INTELLIGENT SENSING SMART STRUCTURES IN ADVANCED COMPOSITES

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ABSTRACT

The emerging trend in the construction of modern aircraft wings as well as in some major civil structures is the adoption of more synergic composite materials. These structures can now be constructed with built-in neurosystems with active control, thereby making themselves smart and behave more like living entities rather than the inanimate edifices. The development of such smart structures is attributed to the advent of new material and processing techniques through multi-disciplinary approach for marrying the fiber optic technology, artificial intelligence and material science with the structural engineering. There is very high potential in developing such smart structures for Defence as well as domestic needs to provide most reliable, accurate and with fail safe technology. Therefore present effort is to develop built-in intelligent sensing inside the modern structures which should also provide the required corrections if any by themselves.

Embedded into civil structure such as in building,bridge, dam etc. or places which are vibration prone, the sensor can detect the vibration or shock effect. The ability of these devices to detect potential weakness in buildings prone to earthquakes or in especially vulnerable structures such as railway bridges and high way overpasses is extremely important.

Embedding fiber optic sensors in GRP monitor residual strain and other key parameters during the cure cycle and while in service as Built in Health condition monitoring.

In this effort the data is generated and reported on the utility of different types of sensors for the purpose which includes new optical and micro-chip based for hard materials and chemical base for soft materials.

REVIEW OF CURRENT STATUS AND CHALLENGES OF SMART STRUCTURES AND INTEGRATED SYSTEMS

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ABSTRACT

A smart structure involves distributed actuators and sensors, and one or more microprocessors that analyze the responses from the sensors and use distributed-parameter control theory to command the actuators to apply localized strains to minimize system response. A smart structure has the capability to respond to a changing external environment (such as loads or shape change) as well as to a changing internal environment (such as damage or failure). It incorporates smart actuators that allow the alteration of system characteristics (such as stiffness or damping) as well as of system response (such as strain or shape) in a controlled manner. Many types of actuators and sensors are being considered, such as piezoelectric materials, shape memory alloys, electrostrictive materials, magnetostrictive materials, electro-rheological fluids and fiber optics. These can be integrated with main load-carrying structures by surface bonding or embedding without causing any significant changes in the mass or structural stiffness of the system.

Numerous applications of smart structures technology to various physical systems are evolving to actively control vibration, noise, aeroelastic stability, damping, shape and stress distribution. Applications range from space systems, fixed-wing and rotary-wing aircraft, automotive, civil structures and machine tools. Much of the early development of smart structures methodology was driven by space applications such as vibration and shape control of large flexible space structures, but now wider applications are envisaged for aeronautical and other systems. Embedded or surface-bonded smart actuators on an airplane wing or helicopter blade will induce alteration of twist/camber of airfoil (shape change), that in turn will cause variation of lift distribution and may help to control status and dynamic aeroelastic problems.

Applications of smart structures technology to aerospace and other systems are expanding rapidly. Major barriers are actuator stroke, reliable data base of smart material characteristics, non-availability of robust distributed parameter control strategies, and non-existent mathematical modeling of smart systems. The objective of this paper is to review the state-of-the-art of smart actuators and sensors and integrated systems and point out the needs for future research.

STRESS AND TEMPERATURE DEPENDENCE OF THE DIRECT PIEZOELECTRIC CHARGE COEFFICIENT IN LEAD ZIRCONATE TITANATE CERAMICS

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ABSTRACT

We describe an experiment in which a ramped or step stress can be applied to a piezoelectric sample and the charge generated on the sample can be determined by measuring the short-circuit current with a very high impedance Keithley 617 Electrometer. The low frequency direct peizoelectric charge coefficient, d_{33}, can then be determined and is found to be substantially nonlinear in stress up to 60 Mpa for all the types of Lead Zirconate Titanate (PZT) that we have studied. When a step stress is applied, the current shows a k/t time dependence and we believe that this is due to the movement of 90° domain walls in the ceramic. The proportionally constant, k, is temperature dependent and our results can be understood on the basis of an activation energy model. Average activation energies for the PZT types studied range from 0.2 to 0.7 eV.

We thankfully acknowledge the financial support received from the Chief of Research and Development, Department of National Defence, Canada, under the Academic Research Programme.

RECENT DEVELOPMENTS IN CERAMIC ACTUATORS

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ABSTRACT

In these several years, piezoelectric and electrostrictive materials have become key components in smart actuator/sensor systems such as precision positioners, miniature ultrasonic motors and adaptive mechanical dampers. This talk reviews recent developments of piezoelectric and related ceramic actuators with particular focus on the improvement of actuator materials, device designs and drive-control techniques of actuators. Developments will be compared among USA, Japan and Europe.

MICRO-MACRO CONSTITUTIVE STUDY OF SINGLE CRYSTAL Cu Al Ni SHAPE MEMORY ALLOYS BY MOIRE INTERFEROMETRY

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ABSTRACT

Micro-macro combined experimental research on the whole deformation field of single crystal CuAlNi shape memory alloy are performed by suing Moire interferometry. The study is focused on the micro-macro correspondence of the deformation of the specimen during stress induced forward and reverse transformations. Two kinds of specimen subjected to uniaxial tension and four point bending are used respectively. The aim of the experiment is to quantitatively relate the macroscopic applied stress with the deformation field in the mesoscale. The role of microstructure factors (such as the effect of relative crystallographic orientation of the specimen with the loading axis, the volume fractions and the kinds of variants involved) will be identified. Special discussions on some important issues such as the effect of cyclic loading; effect of plastic deformation due to dislocations are also given. To separate the total deformation, two kinds of measuring procedures will be used: One is loading-unloading in-situ measurement at different constant temperatures, another is temperature-deformation measurement under a given constant load. The experimental results will be used to check the theoretical predictions of the established model and be used as a comparison with the numerical simulations. Some important micro structure-related deformation features of single crystal SMA especially those under non-uniform stress field are first reported.

PHOTORESPONSIVE PROTEIN-CONDUCTING POLYMER COMPOSITES

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ABSTRACT

This research focuses on the coupling of photoresponsive proteins to conducting electroactive polymer matrices to develop a new class of materials for opto-electronic device applications. The rationale behind this coupling is to harvest the inherent optical properties of naturally occurring protein systems by incorporating them into an environmentally stable and yet electronically active polymer matrix material. In this way the polymer can serve to enhance the processability and ruggedness of the composite, minimize internal resistance which is typical of biological materials, and provide "intelligent" electronic pathways for optimum signal transduction. Towards this goal, novel electrochemical and self-assembly techniques have been developed to immobilize the photo responsive proteins; phycobiliproteins and bacteriorhodopsin into pyrrole, thiophene and aniline based polymers. These techniques have proven to be simple, chemically mild and generic for a variety of biological materials. The fabrication, characterization and the resulting photoelectronic properties of these composites will be discussed.

FIBER LASING DEVICES AND THEIR SENSOR APPLICATIONS POTENTIAL

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ABSTRACT

Fiber amplifiers have revolutionized telecommunication networks. Fiber lasers as well as fiber luminescent devices operate in the wavelength range from 0.4 to 4 micrometers and have found numerous applications in field from spectroscopy to medicine. Since there is a high degree of synergy between such technologies and fiber-optic sensors, fiber lasing devices will have growing importance for fiber-optic smart structures, too, namely in monitoring large artificial or natural structures. The state of the art of the various fiber lasing device technologies is reviewed and their potential for smart sensor applications is discussed.

FAULT DETECTION IN STRUCTURES VIA SMART PROCESSING

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ABSTRACT

This paper deals with techniques for detecting faults in structures where future smart systems need to take account of sensor location, optimal number of sensors and the ability to deal with arbitrary signals. Examples are given of detecting impact energy levels in composite structures via neural networks and how the number of sensors can be optimized via genetic algorithms. The paper concludes with a new approach to fault detection that eliminates the need for "supervised learning" which is one of the main problems associated with neural networks.

DAMAGE ASSESSMENT USING LIQUID FILLED FIBER OPTIC SYSTEMS

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ABSTRACT

The use of liquid core hollow optic fibers for the potential detection of cracking in opaque and semi-opaque brittle materials generated by dynamic or static loading was the topic of this research. The liquid filled hollow fibers carry light and if the fiber cracks, liquid is lost. The remaining liquid projects a diffraction pattern from the meniscus at the ends of the adhesive when light is projected through. The relationship of these patterns are related to the location of the fiber crack and the volume of the crack because the amount of liquid lost into the matrix can be measured.

NON-LINEARITIES IN THE THICKNESS MODE RESPONSE OF PVDF-TRFE COPOLYMERS MADE BY AMP SENSORS LTD.

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ABSTRACT

In smart structures piezoelectric materials are often used under conditions where the non-linear characteristics of the material become important. We have analyzed the first six resonances in impedance spectra of PVDF-TrFE copolymers manufactured by Amp Sensors, Ltd. to determine the frequency dispersion in the complex dielectric, elastic and piezoelectric constants of the material in the thickness mode. The dispersion can be modeled by expressing the constants as polynomials in frequency that fit the data very well over the 1 to 30 MHz frequency range. Further, the field dependence of the material constants was studied by analyzing the variation in the fundamental resonance as a function of an applied bias field and we found that the non-linear field dependence of the material constants of PVDF-TrFE was much smaller than that of similar constants of a soft PZT.

We thankfully acknowledge the financial support received from the Defence Establishment Atlantic of the Department of National Defence, Canada.

RECENT DEVELOPMENTS IN MONITORING AND CONTROL OF SMART CIVIL INFRASTRUCTURE SYSTEMS

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ABSTRACT

This presentation provides as overview of some important research issues related to the general field of structural control. The broad field of structural control is a part of earthquake engineering and deals with a wide spectrum of topics including adaptive structures, intelligent/ smart materials and systems, health monitoring and damage detection, actuators, sensors, and hybrid vibration control of civil infrastructure components under the action of earthquakes, wind and man-made loads. A subset of problems related to near-field ground motion, cracked steel joints, damage detection/condition assessment, base-isolation approaches, performance of critical lifeline systems (including bridges, power systems and hospitals), active control approaches, and strengthening and retrofit of vulnerable structures are considered. For each of these topics, the relevant research issues and technical challenges underscored by the recent earthquakes are discussed. Some promising approaches to alleviate these problems are presented in the context of the broad field of structural control of dispersed civil infrastructure systems. A brief resume of high-priority research topics is presented and is used to illustrate the need for and to motivate sustained international collaboration in the field of structural control research and applications.

NONLINEAR STRUCTURAL CONTROL USING NEURAL NETWORKS

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ABSTRACT

In a recent paper Ghaboussi and Joghataie (1995) presented a structural control method using neural networks, in which a neuro-controller was developed and applied for linear structural control when the response of the structure remained within the linearly elastic range. One of the advantages of the neural networks is that they can learn nonlinear as well as linear control tasks. In this paper, we study the application of the previously developed neuro-control method in nonlinear structural control problems. First, we study the capabilities of the linearly trained neuro-controllers in nonlinear structural control. Next, we train a neuro-controller on the nonlinear data and study its capabilities. These studies are done through numerical simulations, on models of a three story steel frame structure which has become a standard model for testing structural control methods. The control is implemented through an actuator and tendon system in the first floor. The sensor is assumed to be a single accelerometer on the first floor. The acceleration of the first floor as well as the ground acceleration are used as feedback. In the numerical simulations we have considered the actuator dynamics and used a coupled model of the actuator/structure system which was proposed by Ghaboussi and Joghataie (1995). Same as in the previous paper, we have used a realistic sampling period and included an inherent delay in the control loop. These numerical studies are part of an on-going study which includes experimental verification of the neuro-control method. The experiments will be performed on the same three story structure whose model is being used in the numerical simulations.

SATELLITE IMAGE GIS FOR RAPID DAMAGE ASSESSMENT

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ABSTRACT

A system architecture for rapid and reliable emergency response in consequence of suddenly occurring natural disaster is conceived and described, in terms of its major components, throughout this paper.

The final goal of the developed methodology is the integration, within a single user interface environment, of data access and standardization techniques, image processing tools, GIS technology, analytical modeling and communication tools. This would allow to sensibly reduce the effects of the earthquake disaster by providing an immediate estimate of the extent and location of the suffered area and making this knowledge available to the responsible agencies.

In particular, attention is focused on the implementation of the above system architecture distinguishing between local and central nodes in order to gain effectiveness and to optimize the reaction time for an efficient and rapid emergency response.

The local nodes are located in the single municipalities and consists of personal computers where the cartographic and tabular databases are collected and stored. The central one consists of a Unix workstation where the GIS software and the image processing tools are resident.

A NEURAL NETWORK APPROACH TO DAMAGE DETECTION IN A BUILDING FROM AMBIENT VIBRATION MEASUREMENTS

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ABSTARCT

A neural network-based approach is presented for the detection of changes in the characteristics of structure-unknown systems. The approach relies on the use of vibration measurements from a 'healthy' system to train a neural network for identification purposes. Subsequently, the trained network is fed comparable vibration measurements from the same structure under different episodes of response in order to monitor the health of the structure.

It is shown, through simulation studies with linear as well as nonlinear models typically encountered in the applied mechanics field, that the proposed damage detection methodology is capable of detecting relatively small changes in the structural parameters.

The methodology is applied to actual data obtained from ambient vibration measurements on a steel building structure, which was damaged under strong seismic motion caused by the Hyogo-Ken Nanbu Earthquake of 17 January 1995. The measurements were done before and after the repairs, which represents the 'healthy' condition of the building. The trained network, which is subsequently fed data before the repairs, successfully identified the difference between the damaged storey and undamaged storey. Through this study, it is shown that the proposed approach has the potential for being used in practical damage detection methodologies in conjunction with smart civil infrastructure systems.

ENSEMBLE TRAINING OF A BENCHMARK STRUCTURAL CONTROL PROBLEM

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ABSTRACT

In an attempt to further the assessment of effectiveness and implementability of various structural control algorithms the ASCE Committee on Structural Control has designed a benchmark structural control comparison. The problem presented is a three story actively controlled building model with either an active mass driver or an active tendon control system. The prescribed excitations for this study are historic earthquake records and a specified stationary random process.

In civil engineering, the design of active vibration control systems for structures subjected to excitations of this type is often done using linear-quadratic optimal control theory. However, this theory is only able to account for external forcing functions which are known a priori. The benchmark study assumes the foreknowledge of all input excitations. For this type of analysis, the assumption that the excitation is known in advance is questionable. The authors have previously proposed a new method of addressing the issue of including the earthquake-type excitation explicitly in the development of control systems, by designing feedback and feed-forward controllers whose gains are optimized by training on an ensemble of earthquakes (1996). The optimization of the feed-forward controller necessitates the knowledge of the input excitation in advance.

The intent of this study is to examine how close a controller optimized over an ensemble of 'known' earthquakes can come to a similar controller optimized over a single 'known' earthquake and the extent to which either design is appropriate for the real-time control of structures subjected to unknown excitations. The effectiveness of this controller in numerical simulations has previously been shown for a single-degree -of-freedom system. This study presents the results for the benchmark multi-degree-of-freedom system.

The development of the controller follows the general formalism developed by Kabamba and Longman (1983) for the design of optimal controllers of arbitrary prescribed order with quadratic cost functionals. In this formalism, the gradients of the cost functional are obtained in explicit form and involve Liapunov equations.

APPLICABILITY OF CURRENT SMART MATERIALS AND STRUCTURES TECHNOLOGY FOR CIVIL ENGINEERING

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ABSTRACT

The development of smart materials and structures technology was initiated in late eighties although some technological advances in related areas were made before the eighties for different types of applications. It is reasonable to mention that current technological development in this area is primarily driven by the needs related to aerospace, electronics and manufacturing engineering applications. In recent years, attempts have been made to extend this technology for civil engineering structures. Application of fiber-optic sensing technology, in particular, has generated increasing attention for monitoring of civil structures.

The loads, dimensions, frequency and the degree of adaptivity required in civil structures are drastically different from the applications encountered in aerospace and manufacturing engineering. As such there is a critical need to examine the feasibility of current smart materials and structures technology for applications in civil engineering structures. This paper presents a concise review of the applicability of adaptive materials (e.g., piezo ceramics, shape memory alloys, electrorheological fluids), fiber-optic sensing technology, smart control algorithms, smart data processing and internet based monitoring technologies for civil structures such as bridges, buildings, transmission towers, etc. It is expected that this type of critical evaluations would be useful in defining and developing a relevant, feasible and economical smart materials and structures technology for civil engineering structures.

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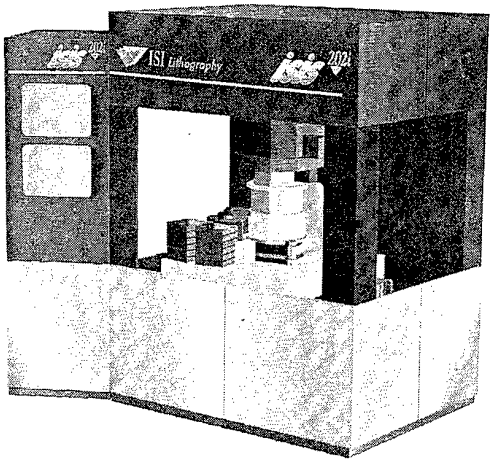

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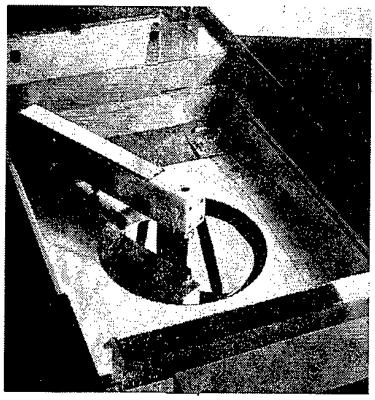

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RELEASE OF SMART REPAIR CHEMICALS FOR THE IN-SERVICE REPAIR OF BRIDGES AND ROADWAYS

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ABSTRACT

Highway repair technologies need a product which can reduce repair time, automatically repair and yet ensure good repair quality, and even accomplish the repair internally while the highway remains in service. The internal time release of repair chemicals when needed is an automatic system which responds to extreme overloads or deteriorating highway conditions while the highway continues in service. This innovative technology is especially suited to bridge structures and pavements. The focus of this research is our use of self-healing concretes in members that are damaged by dynamic events such as earthquakes, impacts. This study investigated the influence of different types of adhesives and release mechanisms in the concrete elements under dynamic load histories. Adhesives with varying damping abilities, stiffnesses, and set times were explored.

IN SERVICE DAMAGE DETECTION METHOD OF PMC BY USING ELECTRIC POTENTIAL METHOD FOR SMART STRUCTURES

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ABSTRACT

Graphite/polymer composites have been applied to many kinds of aircraft primary structures. The composite laminated plate compression properties are easily degraded by delamination and tensile properties are also degraded by matrix cracks. Since these defects are invisible, and real time or in service systems to detect these defects are desired. In this study, an electric potential method was discussed for real time or in service nondestructive evaluation of delaminations and matrix cracks. This method has several advantages in comparison with the embedded optical fiber. For example, this method can be applied to previously fabricated structures by low cost and maintenance of sensors is very easy. Moreover, this method does not cause any decrease of mechanical properties due to implements of sensors.

In order to obtain the basic properties of the CF/epoxy composites, mode I and II delamination tests were carried out. The relations between the electric resistance change and the delamination crack length were measured with delamination test specimens. On these experiments, electrodes were attached in several ways. As a result, the electric resistance bridge circuit approach was proven to be excellent for detecting delaminations from the inside surfaces of aircraft structures.

This method was also adopted to 3-point bending specimens of CF/PEEK that had stacking sequence of $[0_2/90_2]s$ By the increase of an applied load, matrix cracks occurred first, and after that delamination grew from the matrix crack. These defects were distinguishable in the changes of electric resistance. Based on these results, this method was experimentally proved to be applicable to detect damages in this materials.

EMBEDDED PIEZOCERAMICS IN COMPOSITES FOR DAMAGE SENSING AND MITIGATION - DESIGN ISSUES

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ABSTRACT

The use of embedded piezoceramic elements in composite structures provides a simultaneous sensing and actuation capability that has applications in the problem of damage sensing and mitigation. The paper describes an approach wherein strain readings from embedded sensors are used to determine the state of the structure. When a loss in structural integrity is established, compensatory strains are induced in the embedded elements through actuation to control the growth of damage by redistributing the loads around the critical region. Since real-time response is critical for both the sensing and load redistribution operations, the approach studied is one based on using trained neural networks to establish the desired functional relations. Both the sensing operation and any required actuation can benefit significantly from an optimal placement of the piezoceramic elements in the structure. Furthermore, the structure itself should be designed not only for optimal performance under applied loads, but should be most amenable to active damage control.

Both the optimal placement of sensors/actuators in a given base structure, and the integrated design of the base structure with optimally placed sensors/actuators, are generically difficult optimization problems where the design space is nonconvex, and consists of a mix of continuous, discrete and integer design variables. Genetic algorithms are particularly amenable to these class of problems, and were used in this study. The goal of the multiobjective optimization problem was to design a base structure with embedded, optimally placed sensors/ actuators so that three design objectives were attained. First, the ability of the neural network to correctly classify the magnitude and location of damage was maximized. Second, the design of the base structure and the optimally placed sensors/actuators provided the necessary

actuation capability to change load paths away from critically damaged regions. Third, the design was performed under the requirement that a least number of sensors/actuators were required and the system was robust to incidental failures of sensors/actuators. Three distinct modes of damage in a composite structure, fiber breakage, delamination and matrix cracking were considered in the study. Both hygrothermally curvature stable (HTCS) laminates and those with arbitrary stacking sequences were included in the design exercise. The paper will primarily focus on the design approach, the design problem formulation, and results of numerical experiments. A secondary focus will be the analysis model that accounts for embedded peizoceramic elements in arbitrary layered and HTCS composite laminates, with comments on the bounds of practical applicability.

ACTIVE HYBRID CONTROL OF PLATE VIBRATIONS

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ABSTRACT

In this work, which is motivated by recent developments in active structures, control of vibrations of a thin isotropic plate subjected to different spatial disturbance field is considered. The plate is simply supported along all edges, and the plate vibrations are sensed by using point sensors. The control effort is realized by using for the plate-piezo system, and this model is reduced to a finite-dimensional state-space model through a Galerkin projection. This model is used in the numerical studies. Exploiting the advantages of using a direct velocity feedback scheme for controlling broadband disturbances and an adaptive feed forward scheme for controlling narrow band disturbances, a hybrid active scheme is synthesized for controlling the vibrations of a plate subjected to different combinations of temporal disturbances. Although many efforts have been undertaken for controlling plate vibrations, active hybrid schemes based on distributed actuators have not been considered previously.

With a hybrid control scheme using FXLMS control and hybrid control a plate was subjected to a combined temporal disturbance. A feed forward control scheme based on the filtered-x LMS (FXLMS) algorithm is used in one case, and a hybrid control scheme is used in the other case. The better performance of the hybrid scheme is clearly discernible. These and other numerical studies indicate the advantages of an active hybrid scheme to handle different types of temporal disturbances. Furthermore, the results indicate that a hybrid scheme performs better than an adaptive feed forward scheme in the presence of noise in the reference signal.

OPTIMAL PLACEMENT OF A PIEZOELECTRIC PATCH ON PLATE STRUCTURES FOR VIBRATION SUPPRESSION

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ABSTRACT

The object of this work is to develop a method for placement of a single shunted piezoelectric patch to dampen several modes of plate vibration. This goal is accomplished by maximizing the generalized electromechanical coupling coefficient while limiting the eigen values for the modes under consideration. The variation introduced is the location of the center of a square piezoelectric patch. The difficulty in finding the optimal location of the patch is rooted in both the vastly different mode shapes of the plate and the fact that the shunted piezoelectric stiffness is frequency dependent while the frequency is determined by the location of the piezoelectric. A method based on determining the maximum objective function due to a user-specified relationship between the modes of vibration of a given plate will be presented.

Theory of modeling for determining the relative values of the generalized electromechanical coupling coefficient will be shown. This model is combined with an optimization routine to generate prime locations for the placement of piezoelectric patches. The shape of both the overall structure and the piezoelectric patch do not change for different orientations of the patch on the plate. A remeshing algorithm is developed for determining the finite element mesh to be used for each successive function and gradient calculations. A small plate and an electrical chassis box bottom plate are used as optimization examples. The method developed is highly adaptable to changes in structural design, material changes and changes in the relative importance of the modes of vibration. The paper presents the details of modeling, optimization algorithm, sensitivity analysis and numerical results.

SMART ELECTRONICS AND MICROENGINEERING: THE AUSTRALIAN FOCUS

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ABSTRACT

Progress on miniaturization technologies has led to the birth of microengineering, the development of which over the last decade has led to what is called micro electromechanical systems (MEMS). This novel technology involves the miniaturization of mechanics. Just as down scaling of electronics has results in revolutionary advances, micro engineering is poised to produce a revolution of its own. Furthermore, microengineering is based on the technology of microelectronics utilizing the same processes, equipment and skills. It also requires further advances in specific areas. For example, new design rules would have to be defined and implemented in CAD-tool environment and facilities would have to be augmented with specialised equipment such as double-side aligners, and silicon bonding. Properties of materials utilized need to be further investigated mechanically and electronically. Metrology and characterisation techniques need upgrading. With a suitable choice of materials, electronics can be integrated within resulting in systems with decentralized intelligence. Microengineering holds a potential for impact in fields as diverse as automechanics, medicine, information storage and retrieval, fiber optic communications, and unmanned space exploration.

Australian research has achieved considerable progress in design and fabrication of smart micro sensors of various types. Microengineering, on the other hand, is a burgeoning technology but quickly becoming pervasive. It is only a natural step that these technologies should merge and bring experts from various disciplines to join hands in realising smart microsystems. Such systems will be small, robust, integratable, and more importantly can perform self diagnostics and self calibration.

In this paper we will highlight strategies being undertaken and challenges being experienced Australia-wide in fabrication and realisation of smart microengineered systems.

AN ASSEMBLY AND INTERCONNECTION TECHNOLOGY FOR MICROMECHANICAL STRUCTURES USING ANISOTROPIC CONDUCTIVE FILM

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ABSTRACT

The authors propose a new bonding method for the assembly and interconnection of micromechanical structures using anisotropic conductor (ACF) films. This method has the following advantages. Firstly, it requires a relatively short bonding time ($\simeq$10 sec.) and the low bonding temperature of 180°C. Secondly, the surface of the wafer does not have to be activated before the bonding process. Thirdly, there are no dependency of the bonding materials and therefore it can be applied to a wafer and/or glass substrate. Fourthly, selective areas of bonding can be readily achieved, bonding only occurring where the ACF is placed. Finally, if required, the process provides good electrical interconnection between the wafers.

These advantages were confirmed by experiment using both silicon to silicon and silicon to glass. For the experiments 18mm x 14mm x 300μm wafers and glass covered by evaporated aluminum layer of thickness in the range of 0.1μm to 0.3μm were used. The ACF tape was the type 7621F (Sony) having a width of 1.5mm. The bonding process parameters of temperature, pressure, time applied to the sandwich of wafer ACF wafer were all systematically varied in experiment, the optimum conditions being 180°C temperature, 5 kg/cm^2 pressure applied for 10 seconds.

Full details of the process methodology and the bonding mechanism are described in the paper. The process was applied to fabricate a silicon micropump that consists of tree wafers, results indicating excellent sealing and stability characteristics both needed for this application.

NOVEL METHODS FOR DEPOSITING SUPRAMOLECULAR STRUCTURES ON SOLID SUBSTRATES

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ABSTRACT

Amphiphilies are known to form monolayers at air-water interface. Transfer of these mono layers on solid substrate is often done with the help of vertical dip method associated with lateral compression or horizontal touch method. Both the processes are cumbersome and are likely to result into layers with defects. We have developed a method which is simple and straight forward. It consists of formation of Langmuir film at air-subphase interface of a conical through having hydrophobic walls. The subphase is allowed to seep out gradually through the orifices located at the bottom of the trough. As a consequence the Langmuir film slowly starts descending. The tapering hydrophobic walls of the trough causes gradual compression of the film. The film gets deposited onto a substrate located at the center of the trough positioned a few mm below the initial level of the surface of the subphase. The film has been characterized with AFM and has been found to display good quality.

The method is particularly important as it can be readily adapted to scaling up required for industrial applications or scaling down for specialized use.

Laser ablation is often used to etch away organic materials. We have adopted this method to deposit performed organizates onto solid substrate. The method has special advantages as it is free of intervening effects of solvents which are generally encountered in other methods such as spin coating, LB techniques, etc. Moreover, it offers possibility of depositing molecules in a predetermined orientations. Details of the method will be described with reference to SDS incorporated glucose oxidase and performed structures of Riboflavin-lipid systems.

THE FABRICATION OF A THICK NICKEL MICROVALVE WITH TRUNCATED PYRAMID SHAPE

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ABSTRACT

Float type micro valves can be employed in very high output pressure micropumps. They provide a very large forward to reverse flow ratio with a low leakage flow rate at high applied pressures. The valve described in this paper is a strong, thick, three dimensional structure having an excellent match to the valve orifice dimensions. The metal structure having a thick truncated pyramid shape was successfully manufactured using an electroplating process and a silicon mold. The mold was made by anisotropic etching, the truncated shape being defined by <111> crystal planes. Because of the crystal orientation this process allows the valve to fit precisely into the valve orifice.

A 115°C EPW etch solution was used to fabricate a silicon hole using a P type (100) silicon wafer. Next a 200 A° gold layer deposited by thermal evaporation to act as a seed layer for the electroplating process. Chromium was used for its strong adhesion to glass while gold was selected to obtain an easy separation of the metal structure from the substrate after electroplating process is completed. The glass substrate was bonded to the silicon wafer using a positive photoresist .

A fine and uniform nickel structure was obtained using an agitated nickelsulfamate electrolyte, buffered with boric acid. The anode was a sheet of nickel and the current density was 30 mA/cm^2 The process temperature was held at 50°C. After the plating process was finished, the glass separated easily from the mold by using an acetone solution. The electroplated nickel structure was obtained using a lift-off process employing adhesive tape and/or chemically dissolving the silicon away. Full details of process methodology and discussion will be presented in the paper.

MICROMECHANICAL COMPONENTS WITH NOVEL PROPERTIES

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ABSTRACT

Silicon Micromachining techniques (for both surface and bulk) have been used to fabricate Micromechanical components with dimensions of the order of 1-100 microns. Various parts fabricated are cantilever, cross-beam, spiral spring and resonator on Silicon-dioxide and/or metals like Chromium-Gold and Titanium-Gold. This paper describes the fabrication techniques and characterization of these Micromechanical components.

Langmuir-Blodget films or porous materials have been deposited on these silicon dioxide structures to result in novel properties. Taking advantage of the fact that these micro-parts are made of Silicon dioxide, various ceramics can be coated by SOLGEL process or spin-on method, and sintered at higher temperatures like 600-1000°C. During the sintering process, the interface between Silicon dioxide and the deposited material forms silicates, thus resulting in excellent adhesion. The micro-porous so realized surfaces have been used as sensitive moisture/gas detectors.

The trapezoidal pit etched in silicon during fabrication of cantilever structure can be used as a radiation concentrator with the focus at the tip of the cantilever. Small thermal capacity of this micro-device enables its use as a high sensitivity radiation detector.

SMART PROGRAMMABLE REMOTE WIRELESS MEMS AND SAW BASED MICRO ACCELEROMETER AND THEIR APPLICATIONS

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ABSTRACT

The integration of MEMS, SAW devices and required microelectronics is presented in this paper. This unique combination of technologies results in a novel sensor that can be remotely sensed by a microwave system with the advantage of no power requirements or very low power requirements. Such a device is readily compatible with existing Antenna technologies as the SAW device operates at 1 GHz. The microaccelerometer presented is simple in construction and easy to manufacture with existing silicon Micromachining techniques. Depending on the application certain design parameters can be modified to achieve the desired sensitivity. Similar modifications in the microelectronics can also be envisioned. Theoretical analysis and a fabrication method to produce such a device is also presented.

The relatively small size of the sensor makes it an ideal conformal sensor. The accelerometer finds application as air bag deployment sensors, vibration sensors for noise control, deflection and strain sensors, inertial and dimensional positioning systems, ABS/traction control, smart suspension, active roll stabilization and four wheel steering.

HANDS AND BRAINS: HAPTIC SYSTEMS IN HUMANS, ROBOTS AND VIRTUAL REALITY

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ABSTRACT

In humans or machines, haptics refers to the use of hands for manual sensing and manipulation. Haptic interfaces are machines that provide the human user with the ability to touch, feel and manipulate virtual environments or teleoperated remote systems. To build such smart machines a deep understanding of how the human haptic system functions is necessary, it may also provide a blueprint for the organizing principles of smart electromechanical systems in general. In this talk a review of recent progress in the understanding of human haptics and the development of haptic machines will be given. Implications for smart system design, especially in the context of creating multimodal virtual reality will be discussed.

FIBRE OPTIC SENSORS FOR SMART MATERIALS

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ABSTRACT

Optical fibre sensors have significant application in structural monitoring as an integral part of a smart structural material. This paper will examine the principal technologies which can be used to measure strain, temperature, chemical contamination etc. throughout a structure and identify applications which have been demonstrated. The structures which will be considered include bridges, highways and composite components in vehicles. The paper will also examine emerging trends on optical fibre sensors and their possibilities in more advanced smart material configurations.

POLARIMETRIC SENSOR FOR STRAIN MEASUREMENT AND DAMAGE DETECTION

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ABSTRACT

Of the various Fiber Optic based interferometric sensors, the polarimetric sensors are the easiest to use and provide adequate sensitivity for most engineering applications. These sensors are based on the familiar stress (load) induced birefringence noticed in bulk form in the familiar photoelastic method. The difference being that while in traditional photoelasticity, a whole field view of principal stress difference for a thin specimen is observed, Fiber Optic Polarimetric Sensors (FOPS) get the average stress at a point over a relatively larger length of specimen. Thus for quantitative analysis, these sensors would be applicable where the load distribution over the length of sensing fiber is known, while for qualitative analysis such as damage detection in composites it can be used to determine the threshold of damage or debond from the original undamaged state.

This paper will describe both these applications. In addition suitability of both Polarizing maintaining fibers and Single Mode fibers in specific applications will be demonstrated. Furthermore, effect of unstripped and bare fibers will also be evaluated in regards to their sensitivity in each application.

POLARIZATION MODE DISPERSION EFFECTS IN EMBEDDED FIBER OPTIC STRAIN SENSORS

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ABSTRACT

The average strain in a composite laminated plate can be measured by an embedded optical fiber using RF interferometry. Instead of using the rather too sensitive optical interferometry, the light intensity through the embedded fiber is modulated at GHz frequencies and the detected signal is electronically mixed with a reference at the same RF frequency. The resulting signal is the cosine of the RF phase which depends on the optical length of the embedded fiber. With proper choice of the RF frequency, the output of the mixer is directly proportional to the average strain in the laminated plate. In this paper we report extensive strain measurements of polyamide coated fibers embedded in graphite-epoxy composite laminated plates made under high temperature and high pressure. When subjected to tension, the measure strain does increase with the applied force but its value fluctuates around the expected linear dependence. Further investigations of this phenomenon indicate that the embedding process induce significant polarization mode dispersion into the otherwise non-birefringent fiber. Thus, the propagation delay through the embedded fiber changes as a function of the input polarization by as much as 10^{-13} sec. (compared to $<10^{-15}$ sec. for the same length of free fiber). Therefore, the measured strain really depends on the input state of polarization which tends to change as the tension increases.

In summary, polarization effects induced by the embedding process may perturb the linearity of fiber-optic interferometric sensing in smart structures. Techniques for the measurement of polarization mode dispersion will be also discussed.

AIR-QUALITY SENSOR WITH FAST RESPONSE TIME BY SILICON MICROMACHINING

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ABSTRACT

Air quality measurement is quite important in confined environments such as large buildings, aircraft's, mines and so on. A combination temperature sensor and a capacitive type humidity sensor for air-quality measurement, integrated on a single chip, is proposed. The most important advantages of such micromachined sensors are low cost, high reliability low power consumption and miniature size. The structure of the sensor will include a signal processing circuit and a calibration device for the capacitive humidity sensor. Temperature sensing is used to compensate for the non-linear measurement characteristics of the humidity sensitive thin-film and to improve the accuracy of humidity measurement. In view of its good sensitivity over board range of, temperature with quick response and low hysteresis, cellulose acetate is considered as the humidity sensitive material. This material must be deposited as a thin film by means of one of the micromachining processes. A porous structure of the thin film is preferred. The temperature sensor within the proposed air quality sensor is realized by an exposed transistor junction. A standard double poly double metal CMOS process has been used to fabricate the sensor and the microfabrication processes are described.

ADVANCED AND APPLICATIONS IN FIBER OPTIC SMART STRUCTURES

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ABSTRACT

This paper describes the building block technologies required for successful implementation of fiber optic smart structtres. The operational principles of the most promising optical fiber sensor configurations — extrinsic Fabry-Perot and Bragg grating sensors — will be explained first, followed by discussions of signal processing and multiplexing (wavelength division and coherence division) schemes for these sensor configurations. However, the sensor technology is only one of the three building block technologies required for successful fiber optic smart structure implementation. The other two are solid mechanics and sensor data post processing. The solid mechanics, or interaction mechanics as it is sometimes called, deals with (1) how the optical fiber perturbs the local strain state of the host structure, (2) how embedded optical fibers impact structural design, (3) how the fact that the fiber sensors are embedded effects the sensor data interpretation. The final technical building block that will be discussed is how to use the information provided by embedded sensors to make meaningful determinations regarding the performance of host structural systems. This is application specific, and will therefore be dealt with through examples and/or case studies. This paper is intended to provide an appreciation for the optics, signal processing, and solid mechanics required to use fiber optic smart structures in a meaningful way.

INTEGRATED STRUCTURAL TESTING SYSTEMS WITH FIBRE OPTIC SENSORS

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ABSTRACT

Structural testing systems which integrate optical fibre detection with controlled structural parameter provide a reliable and effective system for long term structural condition monitoring since the boundary conditions between the detector and the structure remain essentially constant. Such systems may be applied to civil structures and to monitoring advanced composite materials.

This paper will present and analyze the results of two programs which have been addressing these issues. The first program uses conventional ultrasonic sources and an all fibre Mach Sehnder interferometer as the detector. This is demonstrated that structurally significant damage to composite material panels can indeed be reliably evaluated thereby enabling advanced warning of impending structural deterioration.

In the second program we present the results of a novel moisture monitoring system which detects the onset of corrosion favorable conditions. Whilst this is a passive system, its intent is very similar to that of the ultrasonic testing configuration and functionally the two are effectively identical. The focus in this system is to address structural assessment in large civil engineering insulations.

POLARIZATION DEPENDENCE OF HOLOGRAPHIC SURFACE RELIEF GRATINGS RECORDED ON AZOBENZENE POLYMERS

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ABSTRACT

Recording of surface relief gratings on azobenzene containing side-chain and main-chain polymers has been achieved without any pre or post-processing of the polymers at incident intensity levels of few milliwatts/cm^2 Surface modulation in excess of 3000 A° can be achieved in a micron thick sample of these polymers. The recording process shows a very strong polarization dependence. Interfering beams which are s-polarized record no surface relief gratings while circular, polarized and unpolarized interfering beams induce a large surface modulation. The relationship between the intensity profile and the surface profile has been experimentally established. The erasure characteristics of these gratings are also very sensitive to polarization of the incident beam. A model explaining the recording process is proposed along with some possible applications.

PASSIVE AND ACTIVE (SMART) CHIRAL MATERIALS AND COATINGS - AN OVERVIEW AND APPLICATIONS

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ABSTRACT

The possible use of chiral composites and coatings for the reduction of electromagnetic reflection from metallic surfaces have been already investigated. It has been established that they are efficient absorbers. Varadan and Varadan [1] proposed the use of chiral composite coatings to obtain shielding and absorption of EM waves over a broad range of frequencies. Varadan et.al [2,3] Proposed the Possibility of using a chiral coatings to reduce radar reflection from metallic surfaces. These chiral coatings significantly reduce the reflections over a wide frequency range and angles of incidence regardless of polarization.

In this talk, an overview of chiral technology will be presented with an emphasis of designing both passive and active coatings and composites suitable for various EM applications. Examples of chiral absorbers for antenna structures, shroud and coatings on simple and complex shapes will be given. A hybrid coating suitable for both micro- and millimeter-wave and IR absorption will be also presented.

[1] V. K. Varadan and V. V. Varadan, Electromagnetic shielding and absorptive materials, US Patent 3,948,923 (1990)

[2] V.K.Varadan, V.V.Varadan and A.Lakhtakia, " On the possibility of designing antireflection coatings using chiral composites", Journal of Wave-Material Interaction, 2, pp. 71-82 (1987)

[3] V.K.Varadan, V.V.Varadan and K.S.Jose, " Radar cross section and infrared reduction with conducting and chiral polymer coatings on targets ", Journal of Wave-Material Interaction, 8, pp.297-310(1993)

RECENT TRENDS IN SOME CONDUCTING POLYMER LANGMUIR BLODGETT FILMS

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ABSTRACT

Organized monolayers have recently attracted much interest both for fundamental and technological reasons. In this context, Langmuir Blodgett technique has been considered as one of the most powerful tools to fabricate thin organic films whose structures can be controlled at the molecular level.

Amongst the various materials, conducting polymer Langmuir Blodgett films have been the subject of considerable debate. Langmuir Blodgett films of polyalkylpyrroles and Polyalkylthiophenes, etc., have been reported in literature. Besides this, application of these films to metal-insulator- semiconductor (MIS) and biosensors have recently been demonstrated.

In the present paper, an attempt has been made to describe the work on preparation of Langmuir Blodgett films of conducting polyanilines. UV-visible, FTIR and electro-chemical techniques have been used to characterize such ultra thin films.

STUDIES ON ACTIVE ACOUSTICS CONTROL

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ABSTRACT

Analytical and experimental investigations into active control of sound fields within a three-dimensional enclosure are presented for tonal and bandlimited disturbances. Lead Zirconate Titanate (PZT) patches mounted on the flexible wall of the enclosure are used as distributed actuators, and polyvinylidene fluoride (PVDF) film mounted on the flexible wall and condenser microphones are used as sensors. The sensors and actuators are used in a digital, adaptive feedforward control scheme to realize "local" noise control.

For tonal disturbances, the developed analytical model is found to yield results that are in good agreement with the experimental observations. Different cases of bandlimited disturbances are considered in the experiments. These cases include multiple panel and/or enclosure resonances. For bandlimited disturbances, the control scheme is found to be effective in identifying the dominant resonances and realizing significant noise reductions at the dominant modes. However, the local noise reductions realized for bandlimited disturbances are not as high as those realized for tonal disturbances. Issues such as actuator redundancy and performance functions are also explored in the investigations.

ACTIVE STRUCTURAL CONTROL FOR A SMART ACOUSTIC GUITAR

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ABSTRACT

The field of smart structural acoustics control has been investigated and applied to many aerospace applications. In this paper, we have modified the control techniques and we have applied the principles of smart structural acoustics control to a non-aerospace application. The non-aerospace application is in the field of acoustics of musical instruments. In particular, we have applied smart structures control to make a relatively inexpensive guitar sound like a good quality guitar which is usually expensive. The work was motivated by the fact that a good quality violin like the Mendelssohn Stradivarius violin costs approximately 1.7 million dollars while a typical music store violin costs about two thousand dollars. The actual research consisted of formulating structural dynamic models for guitars, validation of the analytical model by performing tests in an anechoic test facility, in-plane model survey to find the optimum location for piezoceramic sensors and actuators, design of active smart structural controllers, implementation and validation of controllers on a guitar and demonstration of the improved sound quality of the guitar in closed loop conditions. The control objectives included enhancement of certain structural modes while suppressing vibration in other modes, PPF, pole placement and robust controllers are designed. The effectiveness of different controllers are studied in this paper.

ADAPTIVE CONTROL OF DYNAMIC SYSTEMS WITH NONLINEAR PARAMETRIZATIONS AND APPLICATION TO SMART FRICTION COMPENSATION

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ABSTRACT

Most of the results in adaptive control have focused on the control of dynamic systems when the unknown parameters occur linearly. This assumption has been fairly central in the development of adaptive estimation and control strategies, and commonly made in both discrete-time and continuous-time plants. The structure of the dynamic system, choice of estimator, choice of controller have all been selected by and large so as to preserve a linear parametrization. We have recently developed an adaptive controller that is capable of controlling dynamic systems which have nonlinear parametrization. When the state variables of a nonlinear system are available and one or more of the system parameters appear nonlinearly, we have shown that a globally stable adaptive controller can be determined. Both regulation and tracking are shown to be achievable globally. This result expands the scope of adaptive control considerably, which has been restricted hitherto to systems with parameters occurring linearly. In this talk, highlights of this result will be presented. The resulting performance in the context of a high precision machine with dominant friction characteristics will be illustrated. The potential impact on the design of smart structures using such an algorithm will be explored.

UNCERTAINTY MODELS AND ASSOCIATED TRADE-OFFS FOR WING/STORE FLUTTER SUPPRESSION

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ABSTRACT

The problem of active control of wing/store flutter suppression involves many uncertainties which are both parametric and non-parametric in nature. Slow variations of store mass, center of gravity location, etc., are some of the examples of structured or parametric uncertainty while modeling errors such as store aerodynamics which is not taken into account is classified as unstructured uncertainty. These uncertainties can either be reflected at the input or at the output of the plant to capture the inaccuracies into the control loop. However for multivariable systems, the stability margins are not the same at the two points. The objective of this paper is to compare these stability robustness characteristics with uncertainties represented at input and output of the plant. Additive and multiplicative type of uncertainties are used to represent the perturbations while loop transfer recovery (LQG/ LTR) and H_∞ control design techniques are used for closed-loop system analysis.

The approach for control of wing/store flutter suppression involves the use of a piezoceramic wafer actuator as an active decoupler pylon between the wing and the store. The actuator attempts to make the wing torsional mode insensitive to store pitch inertia effects by acting as a low-stiffness strut, while maintaining the alignment between the wing and the store through the closed-loop control system. The proposed actuator consists of a series of thin circular plates with piezoceramic laminated to its opposite sides. The poled directions of the piezoceramics are aligned so that a voltage applied across the element contracts on one side and expands on the other. Straining the piezoceramics in this manner result in bending of the elements that is then translated into an axial motion along the strut.

GENERALIZED IMPEDANCE NETWORKS FOR ACTIVE DEVICE TECHNOLOGIES

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ABSTRACT

Recent development of synthactive© technology for active device systems driven by transductive coupled behavior introduces a wholly new approach to development of active ceramic based systems. The crucial role of variable parameter controls that are described as a new class of generalized impedance networks emerges from this theory. This paper focus is upon the canonical network realization. That is the theory underlying this variable parameter theory of systems governed by active (transductive) behavior and its realization as a new class of generalized impedance networks.

The emergence of an internal structure within the power system and drive electronics for aeromechanical or mechanical systems governed by transductive behavior common to both discrete and continuous electrical-mechanical systems leads to the underlying theory of quasiactive(c) controllers (i.e. operates at high voltage, but with no net energy consumption). If the control is lossless, then it should be possible to implement control in a way which, while it requires a power source, consumes no net energy from the power source. That is a drive/ control mechanism which needs a reservoir of stored energy rather than a continuous source of power. This paper presents a realization of this new controller based upon the concept of generalized synthetic impedance which is termed a synthetic lossless realization. The synthetic concepts and circuitry are introduced and the analog and digital microcontrollers of the controlled coupled parameters are discussed.

The development implies that not only is no net consumed in damping the structure, but that the mechanical energy in the structure can also be recovered. In practice, of course, some energy will be lost in switching and small-signal electronics, but the recovered mechanical energy might be used to compensate for some of these losses. This loss-free impedance implementation is extremely flexible, as the power-handling parts of the system are independent of the desired impedance over a wide range. The impedance is determined by small-signal elements in an analog implementation or by stores values in memory in a digital signal processing implementation. This fact is important not only for flexibility, but also to enable interface with the system modeling and neurocontrol.

DESIGN, DEVELOPMENT AND TESTING OF A SOLID STATE ADAPTIVE ROTOR

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ABSTRACT

This study outlines the analytical tools, design principles, construction techniques and experimental results of a completely new type of helicopter rotor system. This solid state adaptive rotor (SSAR) is the first major departure from the swash-plate and pitch link arrangements which have been employed by rotorcraft for more than 60 years. The SSAR is centered around a twist-active root actuator which is made from an aluminum substrate and directionally attached piezoelectric (DAP) actuators. The base of the DAP torque-plate is rigidly bonded to the rotor shaft while the tip is connected to the root of a conventional rotor blade. Blade motions are allowed by three mechanisms: 1) lead-lag motion is accomplished at the torque-plate/blade juncture which has a built-in flexural lead-lag hinge, 2) flapping is accomplished by bending of the torque-plate, and 3) feathering motions are commanded by the DAP elements. The torsional and coupling stiffnesses and twist deflection characteristics of the torque-plate are predicted by laminated plate theory. A brief comparison of actuator material types shows that the piezoceramics used in the torque-plate have competitive performance as flight control actuators. To demonstrate the capabilities of the SSAR, a½ th Froude-scaled model of a helicopter rotor was built. This model generated blade pitch deflections from -4 deg. to +12° at rates up to 2,500 cycles/min. with no degradation in deflection as RPM increased. Because the full Froude-scaled RPM was only 1001 RPM, the SSAR was capable of pitching at rates in excess of 2.5/rev. which is well within the range for higher harmonic control Further testing showed the SSAR was capable of generating one-way lift coefficient changes in excess of 0.8 with good correlation between theory and experiment.

MODELING OF DAMAGE IN COMPOSITE ROTORCRAFT FLEXBEAMS USING WAVE MODELS

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ABSTRACT

This paper discusses the application of wave propagation analysis to detect damage at structural discontinuities such as boundaries, cracks and delaminations where the underlying structural impedance of the host structure is interrupted or changes as a result of a defect or failure. The approach used involves examining the local scattering properties of structural discontinuities in the frequency domains to assess the effect of damage on the modal response of the structure. A simulated cantilever beam is used to illustrate the performance of the wave model approach for dynamic detection of damage in the form of transverse cracks and mid-plane delaminations imparted to composite rotorcraft flexbeams. Experimental validation is carried out on several graphite-epoxy cantilever beam test specimens with symmetric (0/90), (0/15), and (0/45) ply orientations. Damage in the form of a transverse crack which extends across the entire width of the beam is imparted at depths of 25% and 50% of the beam thickness to each of these test specimens. Similarly, mid-plane delaminations of lengths 1/4", 1/2" and 1" are evaluated for the same composite beam layups. A piezoelectric actuator mounted near the free end of the beam is used to excite structure dynamically to help locate and determine the extent of damage. The resonant frequencies and scattering properties are used as performance metrics to compare the experimental behavior against the analytical predictions from the wave modeling.

DESIGN OF COMPOSITE SMART WING TO ENHANCE ROLL MANEUVER

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ABSTRACT

A pilot provides a rolling maneuver for turning of the aircraft through an aileron system by rotation of trailing edge control surfaces on the right and left wings in a differential sense. The aileron system increases the lift on one wing and decreases lift on the opposite wing resulting in a rolling moment for the rolling maneuver. This is an effective technique for the generation of rolling moment for an aircraft operating in a low dynamic pressure environment where the wings are essentially "rigid". However, if the aircraft is operating at high dynamic pressures where flexibility of the wing is significant, the roll rate is reduced by a detrimental aerodynamic twisting moment produced by the trailing edge control surface rotation. A "roll reversal" dynamic pressure, at which the aileron system is rendered completely ineffective for producing rolling moment on a flexible wing, can be calculated. Traditionally, structural designers stiffen the wings to preclude encountering the reversal dynamic pressure but unfortunately, the additional structural weight results in a degradation of aircraft performance.

Rather than stiffening the wings to avoid encountering the roll reversal dynamic pressure, flexible deformation is here used as an asset rather than an impediment to be overcome, which will enhance the vehicle roll performance. The proper wing re-twisting and re-cambering can be achieved by the use of a distributed smart sensor-actuator network within the wing structure.

In the present paper an analytical approach is presented to provide proper distribution of twist and camber to improve the flexible roll rate. The concept of fictitious control surfaces is developed to introduce an equivalent distributed smart actuator network within the-wing structure to deform the wing to achieve the required flexible roll rate. A full scale finite element model of a realistic wing is considered for this investigation. The presentation will contain detailed discussion of the method developed to retwist the wind to achieve the flexible roll rate and power requirement at different dynamic pressures at subsonic and supersonic Mach numbers.

DEVELOPMENT OF COMPOSITE STRUCTURES FOR STATIC SHAPE CONTROL

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ABSTRACT

The paper presents the design and fabrication of composite structures with embedded sensors and actuators for static shape control. Piezoelectric actuators and fibre optic sensors have successfully been embedded into carbon fibre reinforced epoxy composites. The experimetal specimens have been designed using finite element models. Based on the models, the location and size of the actuators, resolution of sensors and the lay-up of the composites laminates have been developed. Composites have been fabricated with embedded piezoelectric actuators and fibre optic sensors. The paper presents a discussion of the models, experimental results and an analysis of the embedding issues.

AEROSPACE APPLICATIONS OF SMART MATERIALS: EFFORTS AT AEROTECH CORPORATION

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ABSTRACT

Smart materials have gained considerable popularity among the research and scientific communities around the world. Primarily, these materials have been utilized in sensor and actuator applications. This paper will detail the efforts of our company, Aerotech, over the past three years in the area of application of smart materials in the actuation of various aerospace subsystems.

Aerotech recently concluded a two and a half year R&D project for the U.S. Air Force wherein, we developed and tested several mechanisms for air vehicles based on smart materials. Shape memory alloy (SMA)-based flight control surface actuation and deployment of stowed flight surfaces was examined. The project concluded with wind tunnel tests of the prototypes that were developed. A variable camber missile fin with embedded SMA actuators, an AIM-9M Sidewinder-type missile with SMA-driven fore fins for pitch control, and SMA-driven flaps on a high aspect ratio variable camber fin for Tomahawk-type cruise missiles were wind tunnel tested.

Concentrated efforts to develop actuators that provide large displacements and force outputs have recently made available a new class of Ultrasonic Motors (USMs) based on smart materials. The USM is designed to amplify the small displacements produced in a piezoceramic PZT (Lead Zirconium Titanate) ring and transmit the motion to a rotor that is connected to the output shaft via a friction interface. This arrangement provides rotary motion, similar to a conventional electromagnetic motor. This motor can be used to drive various electro-mechanical devices, including subsystems on missiles.

USMs have several advantages over conventional electric motors. Compared to electric motors, USMs are compact and develop large torque for a given size. They produce high torque at low speeds, and therefore require smaller and less complex transmissions. They have fast response, reduced inertia and bounce, and are insensitive to magnetic fields. USMs are non-sparking, quiet, efficient and feature precision movement. When power is turned off, they become friction-locked. Aerotech is developing a flight control surface actuation system for a missile such as the Tomahawk using USMs with toughened PZT elements.

RESEARCH ON SMART MOTORS IN GERMANY

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ABSTRACT

During the last years much work has been done in the field of ultrasonic motors of the rotational and linear type. In these motors the forces and the motion are not generated by electromagnetic fields. Instead, piezoceramic elements are used to excite vibrations in a spatially fixed part of the system (stator). If two modes of vibration are superimposed with a temporal phase shift of 90 degrees then points of the stator's surface move on an elliptically shaped trajectory. If a rigid body, the rotor or slider, is pressed to the stator it will move due to frictional forces.

According to what type of vibration are used different working principles are possible. Some motors are based on coupled longitudinal and bending vibrations, others exploit longitudinal and torsional modes. The most common type used for smart motors is the traveling wave principle which has the advantage of reduced wear in the contact zone.

Though different types of motors have been used successfully in industrial applications, there are still many open problems which have to be solved in order to increase the efficiency and reliability of such devices.

The lecture gives an overview on the latest research done in Germany in the whole field of smart motors. Research topics are both on the mechanical as well a on the electrical side. Also the development of improved motors for a linear motion will be discussed.

ANISOTROPIC PIEZOELECTRIC LAMINATES FOR ROTARY ACTUATORS

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ABSTRACT

In this paper, an innovative actuation principle is introduced for rotary actuators. By taking advantage of material anisotropy, a piezoelectric laminated beam can induce torsional motion from in-plane strain actuation. With this structural coupling, a rotary actuator similar to ultrasonic motors can be implemented. The driving mechanism is a three layer laminated beam with piezoceramic sandwiched between two anti-symmetric composite laminae. Once the piezo-layer is subjected to an electric field, the whole beam will extend and twist resembling the motion of a screw driver. The extension of the beam will bring one end into firm contact with the rotor disk as a clutch mechanism. If the friction between the beam and the disk is large enough, the rotor will rotate with the end of the beam. The clutch is then released when the electric field subsides. In such kind of cycle, the rotor has rotated by a small angle. With this pattern, a continuous and steady rotary motion can be achieved by a set of piezoelectric laminates subjected to cyclic electric field with appropriate phase lag. Since the proposed device is actuated by the direct motion of driving element, the mechanical efficiency will be better than other designs using induced structural vibration. In addition to conceptual design, a prototype of the rotary actuator is fabricated. Actual motion has been observed in the laboratory to verify the proposed device. A parametric study is conducted to investigate the effect of various design parameters for optimum performance.

STATUS REPORT ER CLUTCH BASED LINEAR DRIVE

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ABSTRACT

The present state of development of an electrically adjustable linear motion drive is reported. Design methodologies are indicated which will, when integrated with the characteristics of the electrorheological fluid engagement means, predict the performances of the traverse. Son proof of the techniques used is given for dynamic, thermal and electrical aspects of operation. Approximate sizing data are outlined. Typical potential turn round acceleration (~l00g) and precision of position (<± 1/2 mm) control duty are highlighted.

DESIGN METHODOLOGY OF MAGNETOSTRICTION-BASED ACTUATORS FOR SMART STRUCTURE APPLICATIONS

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ABSTRACT

Magnetostriction-based actuators are finding increased applications in the general area of smart structures. This paper deals with the methodology involved in designing, modeling and control of magnetostriction-based actuators. This methodology will be applicable for designing actuators that use magnetostrictive material from the monolithic rod form to the particulate form. The attainable strain of a magnetostrictive material is given by $\varepsilon = S^H\sigma + d^\sigma H + \alpha\Delta T$ where S is the compliance which is a function of magnetic field intensity, σ is the mechanical: stress, d is the magnetomechanical coupling coefficient which is a function of mechanical stress, is the magnetic field intensity, α is the thermal expansion coefficient and ΔT is the change in the temperature. In this equation, the first term represents the mechanical strain, the second term represents the strain due to applied magnetic field, and the third term represents the thermal strain due to change in the ambient temperature. The third term is primarily due to the resistive heating of the coil used to generate the magnetic field.

The above magneto-thermo-elastic constitutive equation becomes linear if there is no temperature change and the mechanical stress is maintained constant. The linearized equation gives satisfactory results for applications where the actuator is used in a stand alone mode. However, in majority of smart structure applications, the magnetostriction-based actuators are either surface bonded or embedded in a structure. Typically the surface bonded actuators use magnetostrictive material in the form of monolithic rods where as the embedded applications use the magnetostrictive material in the particle form. For both cases, the mechanical stress experienced by the magnetostrictive material varies during the actuation resulting in a nonlinear relationship between the attainable strain and the applied magnetic

field. Further, the attainable strain is affected by the change in ambient temperature, frequency of actuation, magnetic bias, and mechanical preload. In case of the magnetostrictive particles embedded in the host structure, the volume fraction and the orientation of the particles dictate the efficiency of the actuation. This paper, therefore, presents a new design methodology which is most useful to design magnetostriction-based actuators for smart structure applications.

Design examples of both the monolithic rod-based and particle-based actuators are presented. The simulation clearly shows how the parameters such as temperature, frequency of actuation, magnetic bias, and preload affects the performance of the actuators. Also, for the embedded particle actuators, it is shown that the volume fraction (a volumetric ratio between the embedded magnetostrictive particles and the host structure) has a unique optimum value for a given host material.

A TECHNIQUE FOR THE NORMALISATION OF ELECTRO-RHEOLOGICAL FLUID PERFORMANCE DATA IN SHEAR AND PRESSURE/FLOW MODES OF STEADY OPERATION

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ABSTRACT

A technique providing characterisation of electro-rheological fluids per se (as against their apparent device specific performance) is extended by relating data from rotary sliding electrode/ induced shear flow and fixed plane electrode/pressure induced linear 'flow type test rigs. The motion being laminar use is made of the well known Buckingham relationship and the yield stress in the fluid is taken to vary at constant excitation with the condition of the flow.

On the basis of experimental data, the two modes of operation are shown to share continuum fluid characteristics in terms of Hedstrom and Reynolds Numbers at constant excitation and when these are related to a Friction Coefficient, a technique of using "fluid alone" data is made available. This technique allows small sample fluid test results from Couette-type apparatus to be applied conveniently to the prediction of performance of parallel plate valves and clutches operating in the engineering scale.

The properties of an (electro-rheological) ER fluid have been usually stated separately for flow (parallel plate/valve) and shear (concentric plate/clutch) modes of operation. Whilst being convenient to the engineering designer who need confront only two variables, nominal shear rate and uniform electric field, to find the "yield" or electro-stress at a given temperature, the properties do not correspond.

The proposed work is the latest in a series which shows that, for the purposes of engineering quantification and design the properties of an ER fluid at high shear rates and field strengths

can be more effectively unified by use of Buckingham's analyses so long as the time between repetitive on-off excitations is not long. The properties thus derived from tests on one device have been found (without undue error) to predict the performance of another device over the normal range of inter-electrode spacing.

Previous work has shown that from flow studies on what is effectively a Poiseuille-flow type of plane ER valve conducted over a range of pressure and excitation, a common fluid performance is derivable even though the ΔP_V $Q_V E'$ characteristics seem dissimilar for different levels of excitation and valve sizes. This performance was related to the 'static' electro or yield stress of small fluid samples determined ex valve tests on Couette type apparatus, i.e. to the limited applied shear stress at which a pre-excited but initially stationary sample will start to move and, to shear speed data.

This foundation work will be reviewed briefly in order to provide a description of the method, which in the present paper is applied principally to motion at typical device shear shates in a Couette-flow type of steady sliding electrode ER device, and in order to give a basis for comparison and substantiation of the whole technique. In the proposed work this, is extended to another fluid the results of which average more extensively.

COMPUTER AIDED MODELLING APPLIED TO MICROENGINEERED PRESSURE SENSORS

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ABSTRACT

The development of miniaturized diaphragm structures is highly significant to the successful realisation of many microengineered devices. Most industrial designs of physical sensors are now based upon detailed finite element modelling of the mechanical microstructures using software currently available for conventional mechanics. This paper investigates the effects of miniaturisation on corrugated diaphragm structures through the use of advanced computer modelling and simulation techniques. By developing detailed models of the diaphragm structures using commercial finite element analysis software it is possible to investigate the effects on diaphragm performance when the diaphragms are scaled from a macro level (eg. 10 mm diameter) down to a micro level (<1 mm diameter). Case studies are presented and comparisons are made with research work published by other workers. With subsequent sensitivity analysis it is possible to explore the critical design parameters of the microengineered diaphragms, and parameterise the diaphragm such that its performance will be compensated to some degree from limitations imposed by processing parameters.

DESIGN AND DEVELOPMENT OF SMART SKIN ANTENNA USING SAW, MEMS SENSORS AND CHIRAL ABSORBERS

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ABSTRACT

Recently there has been considerable interest toward designing and developing 'smart skins' for aircraft. The smart skin is a composite layer which may contain conformal radar, conformal microstrip or spiral antennas for electromagnetic applications. These embedded antennas will give rise to very low radar cross section (RCS) or can be completely 'hidden' to tracking radar. In addition, they can be used to detect, monitor or even jam other unwanted electromagnetic field signatures.

This paper is designed to address some technical advances made at Penn state in thin, wideband, conformal antenna architecture that is structurally integrable and both structurally and electronically tunable using multifunctional piezo, ferroelectric and chiral materials. The traditional practice has been to design radome and antenna as separate entities and then resolve any interface problems during an integration phase. A structurally integrable conformal antenna, however, demands that the functional components be highly integrated both conceptually and in practice. Our design is to use the lower skin of the radome as a substrate on which the radiator can be made using standard lithography, thick film, MEMS or LTCC techniques. A SAW oscillator circuit along with application specific chip (ASIC) is used to make a unidirectional radome and programmable phase shifters. We will discuss, in particular, conformal skin antenna mounted on a smart thin multiftunctional piezo/chiral polymer shroud which contains microsensors, actuators and microprocessors . This smart skin structure will not only compensate for unwanted structural vibration but also maintain the electromagnetic beam steering and power density (beam shaping). The radiating elements of the antenna are controlled by MEMS based sensors and piezo/chiral actuators. The phase shifting of the

radiating elements is controlled by thin film tunable ferroelectric phase shifters, the dielectric properties of which are changed only by a bias voltage applied between the film and the ground plane [1-3]

1. V. K. Varadan, Smart Electronics and MEMS, SPIE Proceedings, vol. 2722, 1996

2. V.Varadan, F.Sehni and V.V.Varadan, Voltage Tunable Dielectric Ceramics which exhibit Low Dielectric Constan and Applications thereof to Electrical Structures, US Patent (Serial No> 08/260.053) awarded 1996

3. V.K.Varadan, K.A.Jose, V.V.Varadan. R.F.Hughes and J.F.Kelly, " A novel microwave planar phase shifter", Microwave Journal, vol. 38, pp. 244-254, 1994

MODELING OF SINTERING AND THERMAL BEHAVIOR OF CERAMIC THIN FILMS IN MEMS DEVICES

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ABSTRACT

Micro electromechanical Systems (MEMS) has potential to revolutionize the way we perceive and control the environment by merging the advances made in information processing, storage, and display with those in sensors and actuators. Considerable research has been carried out in the areas of manufacturing processes, Computer Aided Design (CAD) of new devices and analysis tools. These activities have produced a wide variety of potential and several commercilized MEMS products. While this body of research has succeeded in advancing the technology itself, very little work has been done in the area of stress analysis, mechanical reliability and failure modes of these multilayered micro-laminates.

This paper presents a unified micromechanics, materials science based model, for predicting the densification behavior and thermomechanical behavior of MEMS containing many thin ceramic layers. A viscoelastic finite element model is developed to simulate both isothermal and constant heating rate sintering of a ceramic thin film on non-sintering and differentially sintering substrate. The Young's modulus, Poisson's ratio and viscosity are assumed to be functions of density and temperature which may in turn be functions of time. The total strain rate for the sintering material is expressed as a sum of elastic, viscous and sintering strain rates. The effect of grain growth will be incorporated implicitly. The material properties needed in the simulation are obtained from the experiments on neat matrix samples.

The parametric study includes the effect of sintering rates, cooling and heating rates, thermomechanical cycling, embedded flaws in the form of cracks and delaminations. Of particular interest is the role of constraint on the sintering rates, residual stresses, film cracking and delamination.

TECHNOLOGIES FOR INTEGRATED SENSORS AND ACTUATORS AT THE DIMES RESEARCH SCHOOL OF THE DELFT UNIVERSITY OF TECHNOLOGY

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ABSTRACT

At the DIMES Research School of the Delft University of Technology several technologies have been developed for the fabrication of micro electro mechanical systems, e.g.sensors and actuators. Micromachining, thin film deposition and wafer-to-wafer bonding technologies have been made compatible to silicon integrated circuitry processing for the realization of smart sensor systems. In this paper the technologies will be described and illustrated with various examples of sensors and actuators, such as integrated lamb wave sensors for fluid properties, adaptive mirrors, and other.

SMART ADAPTIVE STRUCTURES: SOME ANALYTICAL AND COMPUTATIONAL

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ABSTRACT

A need for an optimal or near optimal design of smart and adaptive structures poses many challenging problems in mathematical modeling, analysis, control and computation. This talk will review some recent advances and open research problems in mathematical modeling, distributed and intelligent control systems, and computer-aided prototyping that will enable full exploitation of significant advances in smart material technology.

Mathematical challenges in material science vary with length scale, time scale and temperature requirements. The macroscopic properties of many materials depend in a fundamental way upon fine scale structure of the material. Fine scale structure may also appear in problems of optimal design of materials which possess desired properties. Emphasis will be on modeling, identification and control problems associated with such materials

AN OVERVIEW ON SMART STRUCTURES RESEARCH IN JAPAN

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ABSTRACT

This paper presents a review of some of the recent research and development activities of smart and adaptive structures in Japan. Like in USA, the adaptive structures concept first emerged in the progressive process of structural design and technology development in astronautical applications, such as constructions of artificial satellites deploying an antenna and solar paddles. For the last decade, much work has been done on the creation of adaptive structures concept and the construction of variable geometry structures, etc., at the Institute of Space and Astronautical Science (ISAS). Some detail of early conceptual and geometrical studies performed at ISAS from 1984-1990 was described in Ref.1. Reference 2 presents a good review on the adaptive structure researches in Japan which were reported by 1991. Since then, the smart structure researches and developments have much progressed and ramified into a larger number of technical areas. The author will, therefore, review the research studies published mainly from 1992 on.

The review will cover research topics relating to space deployable structures, adaptive truss structures, control of adaptive structures for shape change and docking, active vibration control of space and earthbound structures and their structural components, etc. A mention will also be made of an ongoing Leading Research Project on R & D of Smart Structural Systems performed by a group of researchers in the governmental institutes, private companies and universities, and sponsored by the Agency of Industrial Science and Technology, MITI.

MILLIROBOTICS FOR MINIMALLY INVASIVE TELESURGERY

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ABSTRACT

There is a revolution taking place in surgery: after two millennia, surgeons are operating without cutting the body open. Minimally invasive techniques such as laparoscopy, bronchioscopy, endoscopy and artheroscopy are being used to reduce significantly the post-operative trauma associated with open surgery. In these procedures laser light sources and tools are introduced through cannulas in small apertures in the body to enable the surgeon to see and operate through small port holes and avoid trauma to muscles. The technological challenge here is to provide surgeons with the feel and dexterity of open surgery in this environment (called telepresence). Since the surgeon is remote from the site of the operation even in the operating theater, it is immediate to conceive of remote surgery for urban trauma, battlefield, and space environments as well as rural health care. We are in the 4th year of a joint project with the surgical department of the University of California, San Francisco and a start up Endorobotics Corporation to build {/em millimeter scale} devices to use as dexterous robots (multi-degree of freedom "hands") inside laparoscopic, endoscopic and perhaps thoracoscopic cannulas. Together with this, we are also working on tactile sensing and teletactile display devices as well as the master input devices (used by the surgeon) for surgical teleoperation. In this short talk, we will give a status report of the work in progress and some video tape of the results thus far.

This is joint work with Michael Cohn, Lara Crawford, Jeffrey Wendlandt, Cenk Cavusoglu, and Profs. Ronald Fearing, Larry Stark (Berkeley) and Profs. Frank Tendrick and Larry Way (UCSF).

BIOCHEMICAL SYNTHESIS OF CONJUGATED POLYMERS FOR OPTO-ELECTRONIC APPLICATIONS

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ABSTRACT

Design and synthesis of polymers for opto-electronic applications has been the focus of interest in the last several years. Many conjugated polymers have been designed and synthesized with limited processability due to the solubility problems. The attempts to solubilize conjugated polymers such as polyanilines involve harsh chemical treatments and are often soluble only in their undoped form. Here, we describe a biochemical method of synthesizing soluble conjugated polymers. Horseradish peroxidase catalyzed oxidative free radical coupling of derivatives of aromatic amines and phenols in the presence of hydrogen peroxide has been ' used for the synthesis of polymers with opto-electronic properties. The properties of these polymers can be tailored by the proper choice of monomers. We discuss the synthesis, characterization and optoelectronic properties of some of the novel polyanilines and polyphenols synthesized in our laboratory. Potential applications of these systems in device fabrication will also be demonstrated.

The financial support from ARO is gratefully acknowledged.

LINEAR AND NONLINEAR OPTICAL PROPERTIES OF BIOENGINEERED MATERIALS

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ABSTRACT

Enzymes are increasingly being utilized for the synthesis and modification of materials, and these catalysts provide competitive technologies in different organic syntheses including acylation, oxidoreduction, condensation and tranesterification among others. Some of these unique functionalities of these catalysts from renewable sources are their selective and fast catalytic rates at ambient conditions of temperature, pH and pressure. We report here the optical properties of conjugated polymers prepared from aromatic amines and phenois, catalyzed by an oxidative enzyme horseradish peroxidase in different organic solvents with small amounts of water. The catalytic condensation reactions were carried out in different reaction media such as: bulk solvent polymerization in the presence of different amounts water where the monomers were dissolved in the water miscible or immiscible solvents; reverse micellar polymerization, where the monomers were self assembled at oil-in-water interface before polymerization in the presence of a detergent; and monolayer polymerization in a Langmuir through where the monomers were ordered and oriented at the air-water interface before polymerization. Linear and third order nonlinear optical properties of these bioengineered polymers prepared in different reaction media were determined and will be

reported. UV/Vis, FTIR and fluorescence spectra of Polymers indicated presence of conjugation in the backbone. Third order nonlinear optical properties of polymers determined by degenerate four wave mixing indicated that third order nonlinear susceptibilities of polymers were three to six orders of magnitude higher than the values obtained with monomers. $\chi^{(3)}$ values of polymer solutions measured using a picosecond pulsed laser were as high as $8x10^{-9}$ esu and nonlinear optical responses were faster than 14 picoseconds.

OPTI-ELECTRONIC CHARACTERIZATION OF BACTERIORHODOPSIN, SEVERAL OF ITS MUTANT FORMS AND ANALOGS

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ABSTRACT

Bacteriorhodopsin (bR) is a light-sensitive protein from Halobacterium salinarium that undergoes a photocycle. During this photocycle the molecule transports a protein from the cytosol, across the purple membrane containing the protein, to the external environment. In this process of proton release and uptake, it passes through a series of intermediate states, each having a distinct lifetime. The photocycle can be modified by specific mutations of the amino acid sequence, by the addition of chemical additives and by substitution of the native chromophore with an analog. Previous studies in this and other laboratories have shown that the last portion of the photocycle, during which proton uptake occurs can be greatly slowed by these modifications. We have already shown that substitution of the 4-keto-retinal for the native retinal to the wild-type bR or the D96N mutant slows the ground state recovery by several orders of magnitude, such that the process normally completed within 1 0 =B55 may require 30 minutes or more to reach ground state.

We have developed a method of measuring the photocurrent produced by the transport of a proton across the purple membrane. This is accomplished by application of a semi-conducting tin oxide electrode, sensitive to small changes in pH. We have found that the 4-keto analog of bR not only shows a photocycle but also produces a photocurrent. We have begun to expand these studies by investigating the first in a series of azulene chromophore analogs and the 9- demethylated form of retinal. We have determined the photo-characteristics and the transporting properties of these bR analogs in both solution and as unoriented non-polymer films on tin oxide electrodes. We have shown that preparing films with low water content has a major effect on the ground state recovery time for the native bR and the chromophore analogs.

The possible application for bR films and monolayers include: information storage and retrieval, gating, switching, holography, and even non-linear optics. The presently available bR molecules do not possess the optimal properties for many of these potential applications. We expect that the study of these designed analogs will give use some insight into the structure/function relationship between amino acid sequence and chromophore structure, eventually allowing use to design a bR molecule with desired characteristics.

LOGIC OPERATIONS WITH BACTERIORHODOPSIN

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ABSTRACT

Bacteriorhodopsin (bR) is a photodynamic protein complex found in the purple membrane of the *Halobacterium halobium*. The initial B state of the bR photocycle has an absorption peak at 570nm while the long lived M state has an absorption peak at 412nm. The B state has a broad absorption band it can be excited with red, yellow or green light. The M state can revert to the initial state via a thermal process or by a photochemical process by excitation with blue light. The lifetime of the M state can be altered by chemical and bioengineering methods. The biopolymer has shown promise as an alternative to conventional materials for applications in information technologies.

We report interesting results on low power phase conjugation, all-optical switching and all - optical light modulation in Bacteriorhodopsin films. All-optical AND and OR logic gates were demonstrated using a two wavelength degenerate four-wave mixing experimental setup.

HORSERADISH PEROXIDASE CATALYZED POLYMERIZATION OF AMPHIPHILIC TYROSINE DERIVATIVES IN MICELLES

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ABSTRACT

There has been much interest in enzyme catalyzed organic synthesis because it allows the design and synthesis of new materials via chemically mild reaction schemes. This study reports on the horseradish peroxidase catalyzed polymerization of amphiphilic, monomer derivates of *d of and l* isomers of tyrosine in micellar solutions. The methodology has been developed to improve the solubility and hence processability of these phenolic polymers. The technique involves the formation of emulsions or micelles of the amphiphilic tyrosines in aqueous medium through manipulation of the solution pH and subsequent enzymatic polymerication. The solution pH, concentration of the substrate (tyrosine derivates and hydrogen peroxide) and the biocatalyst have been optimized for maximum conversion. The physico-chemical properties of the resulting polymers have been studied by various spectroscopic techniques. The stereo-specificity of the reaction has been demonstrated by kinetic methods. Thin films of these polymeric materials have been fabricated and characterized using the Langmuir-Blodgett film technique. The synthesis, spectral characterizations and surface properties of the resulting polymers will be discussed.

Financial support from U.S. Army Research Office and U.S. Army Natick RD&E Center through cooperative agreement DAAH04-94-2-0003 is gratefully acknowledged.

CONTROLLABLE ROTARY DAMPER USING LIQUID CRYSTAL

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ABSTRACT

This paper describes an experimental study on the vibration suppression of rotary shaft using liquid crystal. A controllable rotary damper using liquid crystal with nematic phase is proposed and applied to the vibration suppression of a rotary shaft and a pendulum. Two disks were mounted inside a housing, which were attached to rotary shafts. These disks are free to rotate inside and relative to the housing. Damping is introduced by filling the space between housing and disk with liquid crystal, apparent viscosity of which can be controlled by the applied electric field. The results show that the torsional vibration of the rotary shaft, and the free vibration and parametric resonance of the pendulum are suppressed effectively.

DEFORMATION OF A SHELL STRUCTURE WITH BONDED/EMBEDDED SMART PATCH FOR BIOMEDICAL APPLICATIONS

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ABSTRACT

Vibrations impart cyclic loads to structures and lead to fatigue failure. If the structure is a vehicle, personal comfort is also an issue. To prevent unacceptable level of vibrations or to achieve a desired response to changes in the structural environment, a preferred technique to introduce additional damping in the structures. However, there are situations in which vibration in the sense of creating a cyclic load to cause expansion and contraction of a closed structure is desirable. An outstanding example of this situation is the myocardium, the heart muscle. When artieries that supply blood to the heart become occluded due to heart disease, the heart muscle around the occlusion suffers oxygen depletion and results in a myocardial infarct. The presence of an infarct in the myocardium makes the pumping action of the heart weak thus making the heart dysfunctional. To address this difficulty, the problem of the myocardium with bonded/embedded smart patch which is subjected to an electric field is formulated and the deformations of the myocardium are calculated. The smart patch considered in this study include poly-vinylidene flouride (PVDF) and lead zirconate titanate (PZT).

The deformed configurations are calculated using a finite element method. The electric field is applied in a cyclic fashion to create a volume change in the closed myocardial structure to simulate the pumping action of the heart. The calculated shell-like configurations appear to be compatible with biomedical requirements.

ACTIVE CONTROL OF TOTAL ACOUSTIC POWER RADIATED FROM A VIBRATING STRUCTURE USING SMART SENSORS

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ABSTRACT

This paper considers the design of distributed parameter modal sensors called "smart Sensors", with a particular emphasis on filtering the combination of appropriately weighted vibration modes providing a specific performance index in control strategy. First, by considering a practicability of the distributed parameter smart sensors using PVDF film sensors, onedimensional smart sensor is presented. It is found that the approach done by the one-dimensional sensors holds only the necessary condition for sensing the transformed mode. This problem is overcome by introducing multiple one-dimensional smart sensors. Moreover, the design transformed mode is established. Then, an experiment is conducted, demonstrating the validity of the smart sensors. Finally, using the smart sensors, the minimization of the total acoustic power radiated from a vibrating plate is carried out.

INTELLIGENT CONTROL OF SMART STRUCTURES USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

An overview of the applications of neural networks for intelligent control of smart structures will be presented. Universal mapping and adaptability properties of neural networks have been most extensively utilized in the various identification and control applications that have been reported. We have utilized neural networks as an effective computational tool and integrated it with the structural identification technique called the Eigensystem Realization Algorithm (ERA). The ERA synthesizes a minimal order discrete time state space model from the Markov parameters of a structural system. A multilayered feedforward neural network based method has been developed to estimate the Markov parameters of a structural system from experimental response of the structure to a persistently exciting input. For smart structures, these networks require a large number of neuron in the input and the hidden layers. An accelerated adaptive learning rate algorithm and a selective training procedure has been developed to significantly reduce the learning time and the error performance of the networks.

Various neural network based methods for control of dynamical systems have been studied in the literattre. Neural network based controllers for vibration suppression of smart structures have also been reported. Many of these controllers have been successfully implemented in simulation as well as using PC based data acquisition hardware. With the introduction of the Electronically Trainable Analog Neural Network (ETANN) chip i80170NX by Intel and a digital neural network chip Ni1000 by Nestor Corp., hardware implementation of neural network based controllers has been made possible. The capabilities of the ETANN based robust controller for smart structural systems have been investigated. Robust controllers like

the Linear Quadratic Regulator (LQR) and Linear Quadratic Gaussian with Loop Transfer Recovery (LQG/LTR) have been implemented on a cantilevered plate system using the ETANN chip. Analog hardware components used in the interface between the ETANN chip and the actuator/sensors on the smart structure test article have been developed. Experimental results are also included.

AN ULTRASONIC COMB TRANSDUCER FOR SMART MATERIALS

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ABSTRACT

Installation of a small multi-element comb type ultrasonic transducer is proposed as a component of a smart structure. It can be used in either an active or passive mode in carrying out ultrasonic bulk or guided wave nondestructive evaluation analysis. Theoretical methods are developed and experimental results are presented for guided wave generation and mode control with this very efficient and versatile novel comb type ultrasonic transducer. Excitation and probe design is crucial in mode selection. The comb transducer generates waves which are influenced by such parameters as number of elements, spacing between elements, their size, pulsing sequence, and pressure distributions. The excited elastic field depends on the frequency of excitation, plate thickness and elastic properties. Techniques are studied to optimize the applied loading and the comb transducer design parameters so that only modes which are most sensitive to particular material characteristics can be generated. Complete understanding of the comb transducer parameters and their impact on the elastic field allows us to efficiently generate higher order modes as well as low phase velocity modes which are valuable in composite material characterization. Sample experiments are presented for various plate-like structures.

STRESS ANALYSIS OF PIEZOCERAMICS WITH DEFECTS

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ABSTRACT

Piezoceramics are increasingly used as sensors and actuators in the fabrication of smart structures. The brittle behavior of piezoceramics is a major concern under complex mechanical and electrical loads encountered in the applications of smart structure technology. Stress concentrations due to defects in the material and the openings created during the fabrication may lead to critical cracks that may eventually lead to the failure of a smart structural element. There is an increasing need to develop versatile computational tools for micromechanics problems related to piezoceramics.

It is well known that the boundary element methods are more versatile in the treatment of stress singularities and concentrations. Although the basic boundary element formulation for a piezoelectric material is given by Parton and Kudryavatsev, it has not been implemented and applied to solve practically useful problems. This study presents an alternative indirect boundary element method involving non-singular kernel functions for analysis of defects (processing and fabrication) in piezoceramics. The theoretical development, numerical implementation and selected numerical results are summarized in the proposed paper. The stress concentrations around cavities of various shapes and orientations under mechanical and electrical loads are presented to demonstrate the critical nature of the electroelastic fields. The relevance of present results for design of smart structural element is discussed.

Acknowledgment: This work is supported by NSERC grant A-6507.

SENSORS - PROPERTY - NDE RELATIONSHIPS OF POLYMERIC COMPOSITES PROCESSED THROUGH RESIN INFUSION

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ABSTRACT

Resin infusion (RI), Resin Transfer Molding (RTM), Reaction Injection Molding (RIM), and other liquid molding processes are proven to result in quick demolding of parts, 'are cost-effective and also environmentally friendly. In the current study, a vacuum assisted, rapid fabric wetting, resin infusion process was utilized to fabricate thick section glass/epoxy composites with triaxial and quadriaxial non-crimp weave architectures. A comprehensive set of sensing techniques, including embedded dielectric sensors, thermocouples and ultrasonic methods were adopted to study the flow and extent of cure of the resin in the in-plane and transverse direction through the thick section composites. The performance of the composites embedded with the sensors were studied under drop weight low velocity impact and high strain rate Hopkinson's bar tests. The material and process parameters of interest included variations in fiber volume fraction, placement of resin injection ports and fabric wetting times. Compression failure characteristics of the resin infused laminate were studied in conjunction with acoustic emission (AE) monitoring to determine their performance in light of positioning of the resin inlet and outlet schemes. Compression failure modes were also studied using optical and scanning electron microscopy (OM and SEM). Ultrasonic nondestructive evaluation (NDE) tests were performed for baseline laminate and post-failure analysis.

A COMPARISON OF SECOND TEST PERFORMANCE IN BENDING OF COMPOSITES CONTAINING REPAIR ADHESIVES INTERNALLY RELEASED FROM BRITTLE FIBERS WITH COMPOSITES CONTAINING METAL REINFORCING BARS OR METAL FIBER MATERIALS

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ABSTRACT

Brittle cementitious composites are subjected to force or loads which cause cracking and a potential reduction in material performance. They are, for the most part, heavily reinforced with reinforcing bars or metal fibers to have fracture tolerance.

The subject of this research is the enhancement of strength in bending beyond that available in an original hardened material by the release of "healing" chemicals such as adhesives from hollow fibers into cementitious matrices in response to loading. The sensing of a crack by the fibers breaking starts the activation of a remedial process i.e., the release of a sealing or adhering chemical. This capacity for self-healing occurs whenever and wherever cracks are generated. The research question to be answered is: Will this internally released adhesive and brittle fiber system perform better over the life of the composite than rebar reinforced composites, steel fiber mats, or steel fiber reinforcing.

ON THE ENERGY DISSIPATION OF ACTIVE CONSTRAINED LAYER DAMPING

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ABSTRACT

The shear strains in the visco-elastic cores of beams controlled by Active Constrained Layer Damping (ACLD) treatments are determined and compared with those of beams controlled by Active Control (AC) and conventional Passive Constrained Layer Damping (PCLD) treatments. Such comparison is essential in quantifying the individual contribution of the active and passive damping components, to the overall damping characteristics, when each operates separately and when both are combined to interact in unison as in the ACLD treatments. The comparisons are based on distributed-parameter models which describe the behavior of beams controlled by ACLD as well as beams treated by AC and PCLD treatments. The distributed-parameter models give closed-form expressions for the energy dissipation characteristics of the ACLD treatments in comparison with those of the AC/PCLD treatments. The results obtained indicate that the ACLD treatments are capable of developing shear deformations, in the visco-elastic cores, higher than those generated by the AC/PCLD treatments when the ratio of the longitudinal rigidity of the constraining layer to that of the base beam is less than 1. With such enhanced shear deformation capabilities, the ACLD treatments can develop high damping and effective attenuation of the vibration of critical systems as the blades of rotorcrafts.

A NEW MAGNETIC FIELD BASED WEIGHTED-RESIDUAL QUASI-STATIS FINITE ELEMENT SCHEME FOR MODELING BULK MAGNETOSTRICTION

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ABSTRACT

Deformation control of smart structures and damage detection in smart composites by magneto-tagging are just a few of the increasing number of applications of bulk magneto-strictive materials that are currently being researched. Robust computational models of bulk magneto striction will be of great assistance to designers of smart structures for optimization of performance and development of control strategies. This research focuses on developing 3-D nonlinear finite element models for magneto-strictive structures, based on appropriate variational principles. The differences between the proposed model and available formulations are discussed in detail in this paper.

A lot of research on modeling magneto-strictive materials has been underway since before the development of the technologically important rare earth-iron materials [Brown, 1966; Tiersten 1964 and 1965; Maugin and Eringen, 1972; James and Kinderlehrer, 1991; DeSimone, 1995; Benbouzid, et al, 1993; Claeyssen, et al, 1991]. These works can be classified into three categories based upon their approach - those dealing with the problem at the micromagnetic level, those at the bulk continuum level and those using homogenization techniques to bridge the gap between the above two levels. As of today, the more accurate micromagnetic approaches and the homogenization techniques derived therefrom are too complex to be used to model the engineering applications of smart structures incorporating bulk magneto-strictive materials. Bulk continuum approaches of the day are typically based upon the finite element method, but either use a linear model or do not incorporate all the constitutive nonlinearities inherent in the problem and the governing nonlinearities arising

from the presence of magnetically induced body-forces and body-moments. These approximations, it is felt, can seriously compromise the utility and the reliability of the modeling tool except under special conditions and for special geometries.

A new finite element based modeling scheme is proposed here that attempts to overcome the above disadvantages, vis-a-vis engineering applications. Governing equations for mechanical and magnetic field variables, established by Brown and a number of other early researchers through a micromagnetic approach, are generalized for application at the bulk continuum level after recognizing and stating the conditions of their validity at this level. In view of small magnitudes of magneto-strictive strains available from the best of today's magneto-strictive materials, small deformation conditions are assumed sufficient in the analysis and the mechanical aspects of the constitutive models are appropriately linearized. Each of the differential equations governing the mechanical and magnetic field (i.e., the mechanical equilibrium and Maxwell's equations) are recast in weak form using standard Galerkin techniques. The weak form of Maxwell's divergence-free condition is then imposed as a constraint condition during the simultaneous solution of the mechanical equilibrium equation and Maxwell's curl equation. The weak form presented here is unique in its capability to model the effects of magnetic body forces and body moments. The present formulation seeks to take advantage of the current experimental practice of characterizing magnetic and magneto-mechanical coupling properties of magnetostrictive materials in terms of the magnetic field vector. To this end, a system of finite element equations with magnetic field vector components as nodal magnetic degrees of freedom has been implemented. The above finite element scheme as well as the results of its application to the modeling of experiments on magneto-tagging being carried out by White and co-workers [White, et al, 1996] will be presented.

ACTIVE AND PASSIVE DAMPING OF STRUCTURES

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ABSTRACT

A three dimensional finite element closed loop model has been developed to predict the effects of active/passive damping on a vibrating structure. The example used is a cantilever structure containing a viscoelastic material layer (VEM) sandwiched between a piezoelectric actuator and the base structure. This hybrid arrangement is called an active constrained' layer damper (ACLD). A piezoelectric sensor is also embedded on the structure. The finite element analysis includes a control algorithm to close the loop between the sensor and the actuator. The parametric study considered different types of control as well as geometric parameters related to the ACLD. Comparisons are made between active constrained layer and passive constrained layer, and active damping only. The results demonstrate that ACLD is better for vibration suppression than either the purely passive or active system. the ACLD combines the advantages of passive/active damping techniques and provides higher structural damping with less control gain when compared to the purely active system.

GENERALIZED MIXED VARIATIONAL FORMULA FOR THE ANALYSIS OF LAMINATED PLATES

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ABSTRACT

Generalized mixed variational formula based upon Hamilton's principle is obtained by using Legender's transformation and Lagrange's multipliers. It is used, in general, to deduce the governing equations for laminated composite structures. A rational higher-order displacementbased two-dimensional theory for the analysis of laminated plates is presented. This theory is established using the generalized mixed variational formula to study the vibration behavior of symmetric laminated anisotropic plates subjected to normal and tangential traction fields. Fundamental frequencies are obtained according to the classical, first- and higher-order plate theories. Results are compared with other approximate available in the literature.

MICROMECHANICS OF SMART ACTUATION AND SENSING

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ABSTRACT

This paper will discuss mechanisms of actuation and sensing at materials and structures level. The nonlinear constitutive modeling of piezoelectric and shape memory materials will be presented. A comprehensive model that builds on the unit crystal structure and incorporates Polycrystalline material aspects will be considered. The comprehensive model is based on spin models, Landau theory and Preisach model. It describes polling reversal and depolling behavior of the bulk piezoceramic material, differences between hard and soft piezoceramics and behavior under large stress and electric fields.

The mechanisms of load transfer between parent structure and embedded smart patches will be discussed at the structures level. Numerical and experimental results will be presented. Static as well as dynamic load transfer mechanisms will be presented.

QUSASICONTINUUM ANALYSIS OF PHASE TRANSFORMATIONS IN SHAPE MEMORY ALLOYS

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ABSTRACT

The reversible thermoelastic martensitic transformation occurring in shape memory alloys is a manifestation of complex microstructural behavior. Factors such as aging, homogeneity, anisotropy, texture, grain size, and processing influence these transformations-and the amount of recoverable strains. A purely phenomenological model of the shape memory behavior will not be able to account for different material systems, and most of the factors mentioned above. An alternative route is to study these phase transformations from an atomistic point of view. However, even using techniques such as lattice statics (strictly speaking dynamics should be included), the demand on the computational resources is severe. A middle path seems attractive. We propose a continuum model that uses the constitutive properties derived from an atomistic potential such as the embedded atom method. This approach, referred to as the quasicontinuum approach (Tadmor et al, 1995), marries the continuum and atomistic length scales. We will present results on simulations of phase transformations in Ti and NiTi, and compare the results with both purely continuum and atomistic simulations.

SMART TAILORING OF HYBRID COMPOSITE LAMINATES WITH IMPROVED DYNAMIC RESPONSE

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ABSTRACT

Dynamic response study of hybrid composite laminated plate structures and their tailoring aspects to enhance damping have been discussed in this paper. The present analytical formulation is based on an integrated approach in which the lamina level micromechanics based theory is properly combined with a transverse shear deformable plate theory to predict the equivalent material specific damping capacity (SDC) of a general hybrid composite laminated plate structure. The micromechanical equations based on the mechanics of material approach are used for the calculation of elastic stiffness and SDC at the lamina level. The primary objective of the present study is to get a first hand information on the dynamic response behavior of hybrid composite laminate taking into account both material damping and transverse shear deformation effects. To investigate the damped transient response of a hybrid composite plate subjected to dynamic loading, the governing differential equations were first formulated and then integrated by Newark- β method. As a typical example, the solution procedures of a steady state dynamic characteristics including the modal SDC of a rectangular laminated plate simply-supported on all the four edges have also been discussed. Specifically, our aim is to evaluate the effects of fiber orientation and the volume fraction of the hybridizing fiber on the damped transient response, flexural vibration frequencies and the modal SDC of the laminated plates. Numerical results are furnished for a typical Carbon-Glass fiber hybrid composite laminated plate to understand the above mentioned effects. The influences of Glass fiber volume fraction and fiber orientation were found to affect the damped response significantly. It is also observed that the fiber orientation has a strong influence in controlling the SDC of laminated plate similar to those of the natural frequencies of the plate. The modal SDC of the first three modes indicates that the trend of the SDC variation with respect to laminate fiber angle is in a reversed manner as those of the natural frequencies.

FINITE SIGNAL TO NOISE MODELS FOR SMART STRUCTURES

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ABSTRACT

Electrothermomechanical materials demonstrate noise properties that are not captured by the classical noise model (which assumes a noise independent of the signal). The newly introduced Finite Signal-to-Noise (FSN) models of noise allow white noises whose intensity depends affinity on signal variances. Control theories for this kind of model are not available. This paper provides a complete solution for the analysis and synthesis of linear smart structural systems with FSN model uncertainty. The linear variance operator is a key mechanism used to deduce results for stability and performance robust to these uncertainties. Although the analysis of FSN uncertainty can be conducted by the LMI approach, the analysis conducted here aims for output feedback control synthesis, and the numerical algorithm is simpler and more efficient than the LMI approach. The optimal controller, which optimizes the robustness measure $/mu_{/fsn}$ considered in this paper, is proven to be one that solves an optimal variance control problem with properly chosen weight and disturbance intensity.

PIEZO-CERAMIC SENSOR AND ACTUATOR OPTIMAL LOCATION IN MODAL CONTROL OF COMPLEX FLEXIBLE STRUCTURE

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ABSTRACT

This paper concerns the active structural control using the modified independent modal control method (MIMSC). Distributed sensors and actuators are of PZT ceramics. The studied system is constituted from three shaped plates which are soldered. The shape and location optimization of the sensors and the actuators are dealt with in this study. A modal filtering concept is then introduced in order to extract the modal particiations of the controlled modes by minimizing the effects of the unwanted modes. A numerical and experimental validations were carried out. In the last one, the impedance adaptation problem between sensors and acquisition system is solved. Moreover, analogous filters are designed to smooth the control signal which is delivered by a DSP card as the response of a zero-order-hold filter to a continuous signal.

SYNTHACTIVE THEORY: THIN PLATES WITH MULTIPLE PIEZOELECTRIC COUPLED ELEMENTS

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ABSTRACT

This paper presents new research on synthactive© systems that introduces a new generation of high power density as opposed to high energy density active systems that incorporate transductive (e.g. PMN, PZT, PLZT, etc.) mechanisms that provide the control action. The paper will focus on piezoelectronic© theory for piezo-coupled elastic plate structures. We will present a new multi-modal theory of decoupled quasi-active© controllers electrical-mechanical analysis sufficient to describe the new results in modal control for plate structures with multiple attached peizoelectric elements. It will be demonstrated that the correct method for designing coupled systems whose control action is implemented by piezoelectric devices or mechanisms requires high power but has negligible net energy consumption i.e. *they require an energy source not a power source*. The research model is validated using the circular elastic plate experiment within the NASA Langley Transmission Loss Facility that is being used to evaluate active device technology applications to reduction of transmitted acoustic radiated noise into an interior cavity.

The paper develops semi-autonomous self-governing arrays and insight into the best location of these devices. The multimodal situation will be detailed from a very general viewpoint, then focus on its implications to viable piezoelectronics development for single devices controlling multiple (2) modes from the aspect of multiple devices controlling multiple modes.

These results provide exactly the necessary theoretical foundation for a practical algorithm that will be accomplished in the next reporting period.

The non-uniform plate model will be taken as the starting point for the consideration of modal control with multiple piezoelectric element. The correctly derived V-I relationship for a conceptual flexible plate model with multiple modes and corresponding multiple piezoelectric elements is presented. The introduction of the correct two-port electrical mechanical model is shown and the introduction of the diagonalized generalized state (or PD) feedback law enables the proof that the voltage at each spatial location (x,y) depends only upon the sensed current at that location.

DYNAMIC MODELING AND NEURAL CONTROL OF COMPOSITE SHELLS USING PIEZOELECTRIC DEVICES

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ABSTRACT

A finite element model of a laminated doubly curved shell with integrated piezoelectric sensors and actuators is developed. The formulation is based on the shear deformation theory and is applicable for both thin and thick laminated composite shells. The mode superposition method is used to transform the coupled finite element equations of motion in the physical coordinates into a set of reduced uncoupled equations in model coordinates. The performance of the LQG/LTR controller for vibration suppression is verified for various arbitrary initial conditions.

A system of neural network is then trained to emulate the robust controller. The neural network system is trained using the back propagation algorithm. After suitable training, the neural network controller is shown to effectively control the vibrations of the composite shell. A robustness study including structural parameter variation and loss of sensor output is performed. The neural network controller is shown to provide robustness and control capabilities equivalent to that of the LQG/LTR controller.

ENGINEERING DEVELOPMENT PROCESS FOR MICROELECTROMECHANICAL SYSTEMS: AN INITIAL INVESTIGATIVE STUDY

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ABSTRACT

Research in Microelectromechanical Systems (MEMS) has focused primarily on specific new MEMS devices, new manufacturing processes and the development of MEMS Computer Aided Design (CAD) and analysis tools. These activities have produced a wide variety of potential and several commercialized MEMS products. While this body of research has succeeded in advancing the technology itself, little attention has been paid to the actual engineering development process for designing successful MEMS-based devices.

An area of considerable research over the past two decades has been in New Product Development (NPD) processes for high technology products. One important stage in the NPD process is the engineering development stage. It is here that the system requirements are transformed into a physical product and manufacturing process.

The engineering development process for MEMS products is largely undefined at this point in time and requires in depth study. It has been suggested that the reason for the slower than anticipated growth of the MEMS industry is this lack of understanding in engineering development.

This paper presents an initial study to define a rational engineering design and development process for MEMS products. The paper is divided into three main sections: 1 characterization of MEMS technology, 2 mapping of MEMS technology along selected engineering development dimensions, and 3 synthesizing a rational engineering development process.

The first section of the study characterizes of MEMS technology. MEMS is a "process intensive" technology, meaning that products are highly constrained by the manufacturing process. Simultaneous design (concurrent product and manufacturing process design) is not just a good idea for MEMS but is essential. MEMS differs significantly from microelectronics in that a MEMS device may encompass an entire closed loop system including sensors, actuators and electronics.

In the second section, MEMS technology is then mapped against selected dimensions for engineering development such as:

* Availability of design tools.
* Complexity of MEMS device.
* Ability to Construct prototypes.
* Degree of integration with the electronics.
* Newness of product and manufacturing process to the firm.
* Component versus architectural changes.
* Maturity of the technology.

Analysis of the first dimension, availability of design tools, reveals that many simulation analysis and CAD tools need to be developed to put MEMS design at par with, say, microelectronics design. Since the design tools are not yet widespread, the technical development process must involve significant prototype fabrication and testing. One can see from this simple example the impact of MEMS characteristics on defining an optimal engineering development process.

The final part of the study synthesizes a framework for an engineering development process for MEMS systems. This framework shows a highly integrated product and process oriented design team is required. The engineering design process consists of dual process/product development stages. The number of stages in the process depends primarily on the number of critical decision points which can be identified. The proper team structure varies from a project matrix to a functional matrix as the project proceeds and the roles of each member become well defined.

MEMS FOR MEASURING DEFLECTION, ACCELERATION AND DEICING OF HELICOPTER

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Alumni Distinguished Professors of
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and

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ABSTRACT

Smart MEMS (MicroElectroMechanical Systems) in the form of integrated sensors and actuators offer significant potential for many rotorcraft applications. Sensing of flex beam deflection and acceleration, ice formation and deicing are major candidate areas where smart conformal MEMS based sensors can be exploited by the rotorcraft community. The major technical barrier of the present day smart structures technology is the need for wired communication between sensors and actuators in the rotating system and controllers, data storage units, and cockpit avionics. Many proposed sensors and actuators are commonly distributed either along the blade length or, in the active flap devices, out near the 75% blade radial station. Also they are not conformal to the airfoil shape of the rotor blades. The communication between rotating and fixed systems is typically accomplished using complex slip ring assemblies transferring electronic information down through the rotor shaft. Although advances have been made in wired communication, these complex assemblies are essentially similar to test hardware and present numerous reliability and maintainability limitations when implemented on a production scale. Considering these limitations, development of a wireless means of communication through a new generation Of conformal sensors with built-in antenna, akin to telemetry, could have a dramatic beneficial payoff for rotorcraft applications.

EFFECT OF TITANIUM-SILICIDE COATING ON THE ELECTRICAL CHARACTERISTICS OF FIELD EMITTERS

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ABSTRACT

Micromachined field emitter microtips for field emission displays are fast becoming the dominant technology of flat panel display. While not yet established commercially, the technology shows great promise for low cost and high performance, commensurate with today's slim and portable electronics.

Fabrication capability and shape control have neared perfection, yet current emission and current instability have a long way to go before finding wide applications in vacuum microelectronics devices. Several approaches have been devised to overcome these limitations. For example coating the bare silicon tip with some hard protective layer or some refractory material has been proven to enhance the emission and improve stability, albeit some of these processes are not compatible with triode type arrays.

We set out to experiment with few refractory materials and analyse the pros and cons of these silicides. Recently we published elsewhere the results of a study on Chromium silicide coating and its effect on improving stability with time. In this paper we propose to present an investigation of titanium silicide and its impact on the electrical and emission characteristic of the emitters. Data are also compared with chromium silicidation and some useful deductions will be drawn.

In this experiment 3 inch silicon wafers of (100) orientation and 1-10 cm resistivity were used as a starting material. Fabrication of the microtips was carried out by wet chemical

etching described elsewhere. Titanium was deposited by sputtering immediately after treatment of silicon microtips with buffered HF. Two-step annealing at 700 and 735 followed for stabilization. While the threshold voltage for emission increased slightly, the maximum current extractable also increased over its chromium counterpart. Moreover, Titanium exhibits a higher discharge resistance than Chromium. These findings can be explained by the reduced number of chemically active sites the silicon surface, hence resulting in a silicide-protected and chemically stable layer, suitable for prolonged operation.

PLANARIZATION TECHNIQUES FOR MEMS: ENABLING NEW STRUCTURES AND ENHANCING MANUFACTURABILITY

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Albuquerque,NM 87185-1080

ABSTRACT

Planarization techniques such as chemical-mechanical polishing (CMP) have emerged as enabling technologies for the manufacturing of multi-level metal interconnects used in high density Integrated Circuits (IC). An overview of general planarization techniques for MicroElectroMechanical Systems (MEMS) and, in particular, the extension of CMP from submicron IC manufacttring to the fabrication of complex surface-micromachined MEMS will be presented. Planarization technique alleviates processing problems associated with fabrication of multi-level polysilicon structures, eliminates design constraints linked with non-planar topography, and provides an avenue for integrating different process technologies. The CMP process and present examples of the use of CMP in fabricating MEMS devices such as microengines, pressure sensors, and proof masses for accelerometers along with its use for monolithically integrating MEMS devices with microelectronics will be presented.

SMART TRIM PANEL FOR NOISE SUPPRESSION USING MEMS SENSORS

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ABSTRACT

Active sound transmission control using sensor and actuator on a thin trim panel is investigated experimentally. A performance comparison is investigated between MEMS sensor and PZT sensor. The panel made of aluminum covers the opening of an enclosure where a sound source is located. The outside acoustic field is measured by a microphone array, which scans a hemispherical surface. the isolation performance of the panel is poor at its resonance frequencies. The sound transmission through the panel is actively controlled at the resonance frequencies. A one-sensor one actuator control system minimizes the sensor output by applying a proper electric voltage to the actuator. Global sound reduction of 15-22 dB is achieved at the first three resonance frequencies by using MEMS sensor or PZT sensor and PZT actuator.

DYNAMICAL FINITE ELEMENT MODELS FOR MEMS AND SMART STRUCTURES

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ABSTRACT

Advances in applications of MEMS to smart structures can be accelerated by implementation of CAD tools, optimization and parametric studies which will result in rapid prototyping and *virtual design*. Dynamical finite element models are ideally suited to capture the complexity of active sensor and actuator devices that make up a smart structure. MEMS are miniature electromechanical devices that can also be modeled by FE analysis. Recent advances in FE analysis allows us to zoom in and magnify the mesh at desired locations while maintaining the larger structural model. Thus we can achieve economy in computational time without sacrificing accuracy. In designing a smart structure, the active devices whether they be MEMS or larger devices must be modeled in detail, with special attention to the coupled fields present in these devices (electric, magnetic, elastic, thermal, etc.) and the accompanying additional boundary conditions. Lumped parameter approximations are usually insufficient to describe the observed behavior of these devices. During optimization procedures, one must have the ability to move these devices on the structure and hence one needs automatic remeshing procedures.

This talk will review finite element models for smart structures as they have evolved over the last decade and summarize some of the more recent advances for dynamical modeling of MEMS and smart structures including closed loop modeling and design optimization. Practical examples as well as comparisons and code validation with experimental results will be provided wherever possible.

NUMERICAL MODELING OF SHAPE MEMORY BEHAVIOR USING A CONTINUUM CONSTITUTIVE MODEL

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ABSTRACT

Phenomenological continuum models of shape memory behavior are based on either a purely macroscopic approach or on volume averages over a representative volume element consisting of several grains. These constitutive models attempt to model the shape memory behavior using macro/micromechanics and thermodynamics. In general, these models share a common feature. They describe the martensitic phase transformation by a parameter representing the martensite volume fraction, and formulate an evolution law for the martensite volume fraction. We describe a finite element formulation of a micromechanics based constitutive model that exploits the strong similarity of such models to elastoplasticity. Several other models can be formulated in a similar way, and the present work can be seen as a testbed approach to study and evaluate the constitutive models on a common platform. We present numerical results for Au-47.5at%Cd and Ti-50.6at%Ni to validate the finite element formulation.

Acknowledgment: The support of this research by ARO through Grant No. DAAHO4-96-1-0080 is gratefully acknowledged.

FINITE ELEMENT MODELING OF ACTIVE CABIN NOISE CONTROL PROBLEMS

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ABSTRACT

Piezoelectric Smart Structures are very promising technique in noise control problems. In the cabin noise control problem, the noise source is located outside the cabin and the noise propagates into the interior region through the structure. Thus, a good approach is needed to model the cabin structure as well as the interior acoustic medium. The cabin is modeled as a rectangular box. All sides of the box except one are assumed to have rigid walls. the non-rigid side of the box is a sound permeable plate. Piezoelectric sensors and actuators are mounted on the plate structure and this structure is modeled using a 3-D finite element method which uses a combination of three dimensional piezoelectric, flat shell and transition elements. Previously this same model was used to model the case when the noise source is inside the box and the exterior radiated noise had to be controlled. The acoustic medium is modeled using displacement based finite elements. Numerical results will show the pressure field distribution inside the cabin. The effect of piezoelectric actuators and sensors on cavity resonance will be examined first. The locations, size as well as the applied voltages on the active devices are the tested parameters to reduce noise inside the cabin.

STRUCTURAL MODELING OF AMORPHOUS CONDUCTING CARBON FILM

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ABSTRACT

Amorphous conducting carbon film (conductivity ~ 102 S.cm-1) is prepared by plasma assisted CVD. Conductivity of these films is measured from 300 K down to 4.2 K. From Raman, ESR, IR, photo emission spectroscopy and radial distribution function a polymeric network is proposed along with graphitic clusters. TEM picture shows globular clusters inside the film. Simulation studies are carried out for micron size spherical carbon balls with concentric spherical layers. These balls are connected by polymeric network. The structure of the carbon balls at different temperatures is studied by simulated annealing using molecular dynamics simulation. The size of the balls increases with temperature. Electronic structure of the carbon films is performed by recursion cluster calculation. From electronic structure the gap between the two fundamental bands is found to decrease with optimization of preparation conditions. A correlation between the observed properties and simulated structure is established.

SCATTERING FROM CHIRAL COMPOSITES

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ABSTRACT

The application of chiral composites in the reduction of the radar cross section is now well established. In this paper, the extended T-matrix method and the modified MIE solutions are used to compute RCS reduction possible with chiral coatings. Several scatterer shapes including the sphere, cylinder and oblate spheroid have been taken up for illustration. The RCS reduction obtained using chiral coatings has been compared with conventional RAMs.

In all cases an RCS reduction of around 10-15 dB better than RAM and over a wide frequency range has been observed. A brief discussion on the possible mechanisms that can be attributed to cause this reduction in RCS is also included.

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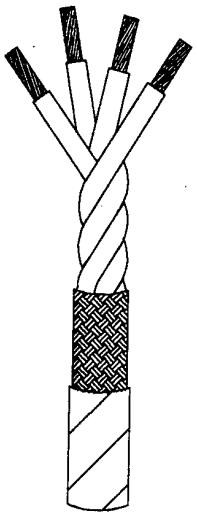

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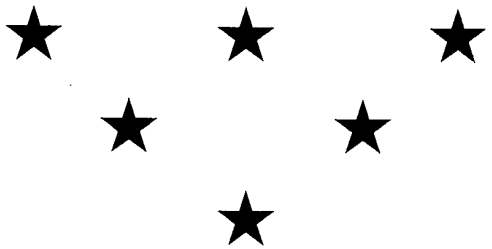

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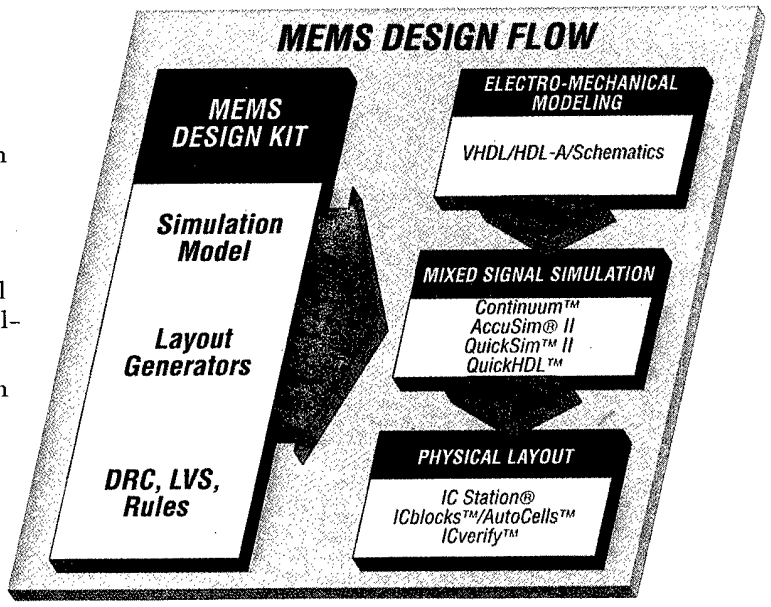

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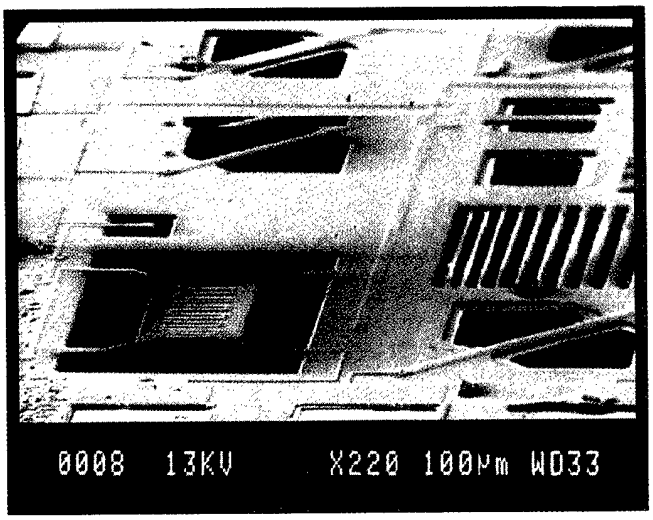

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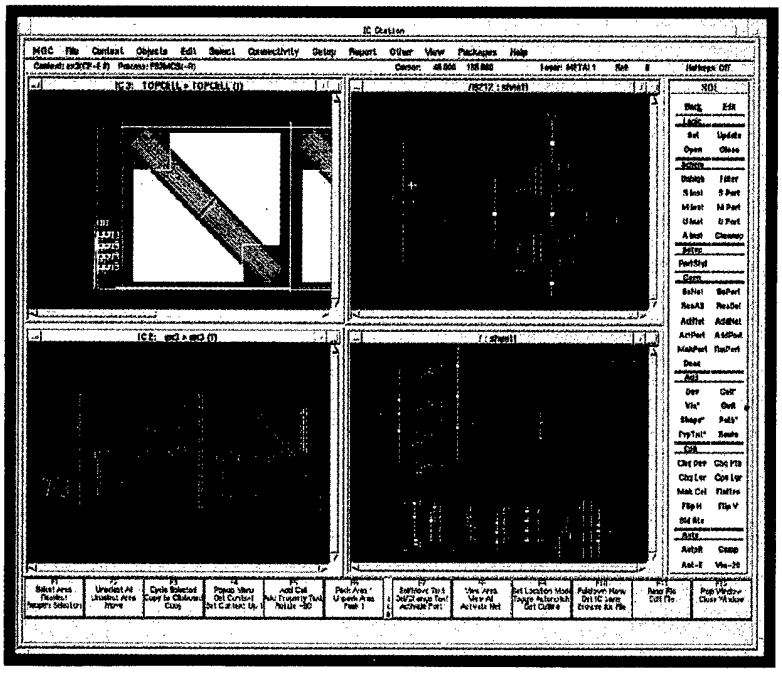
- VITESSE: 0.6µ GaAs MESFET™-compatible front-side bulk micromachining
- PHILIPS: 0.2µ GaAs HEMT™-compatible front-side bulk micromachining



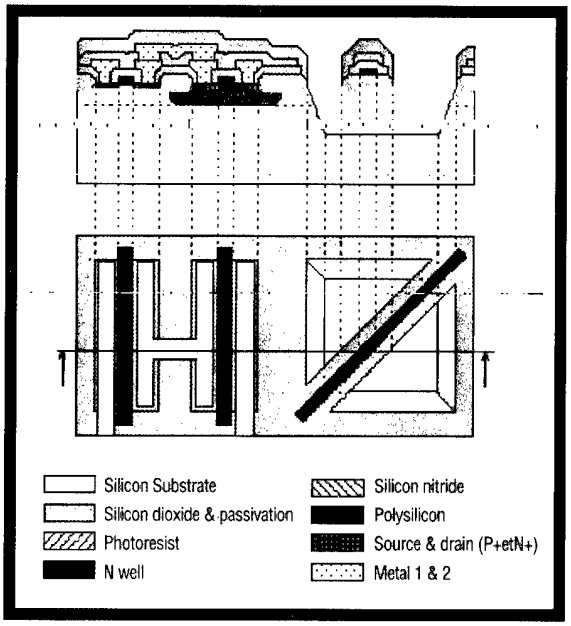
Microbridge layout

Mixed-Signal/ Mechanical Design Flow

- VHDL/Verilog and HDL-A support for mixed-signal electronic modeling
- HDL-A modeling of electro-mechanical components
- Continuum mixed-signal simulation environment supports mixed device, transistor, gate, HDL (logic, analog, non-electrical)

Dedicated MEMS Library and Process Support

- HDL-A simulation models for electro-mechanical systems:
  - Pressure sensor
  - Electro-thermal converter
  - Magnetic sensor
  - Chemical sensor (ISFET)
  - Gas flow sensor
  - Infrared detector
  - Accelerometers (10 different types)
  - Electro-thermo-pneumatic micro-pump
- Process-independent layout generators for mechanical structures:
  - Bridges
  - Membranes
  - Cantilevers
  - Generic structures
- Parameterized design rules for DRC and LVS



Profile and plain view of microbridge and driver

Mentor Graphics®

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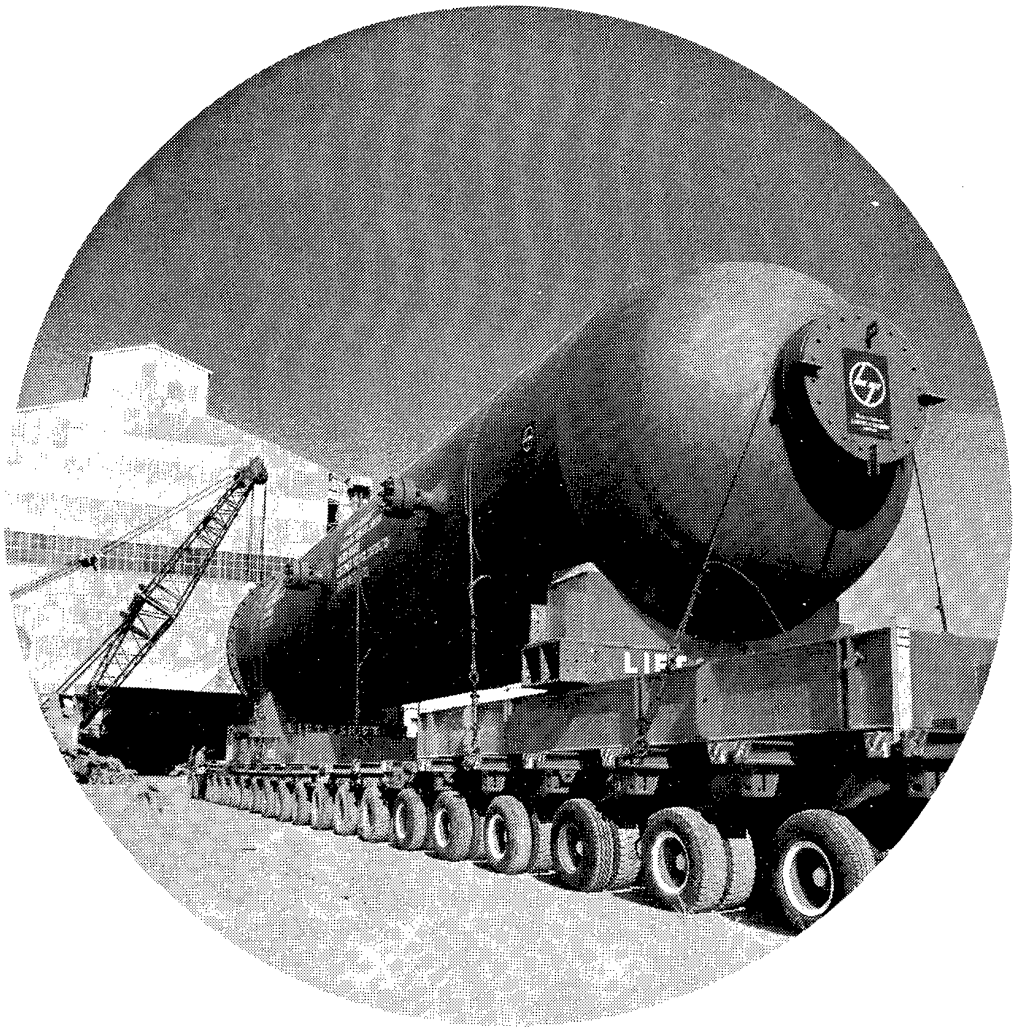

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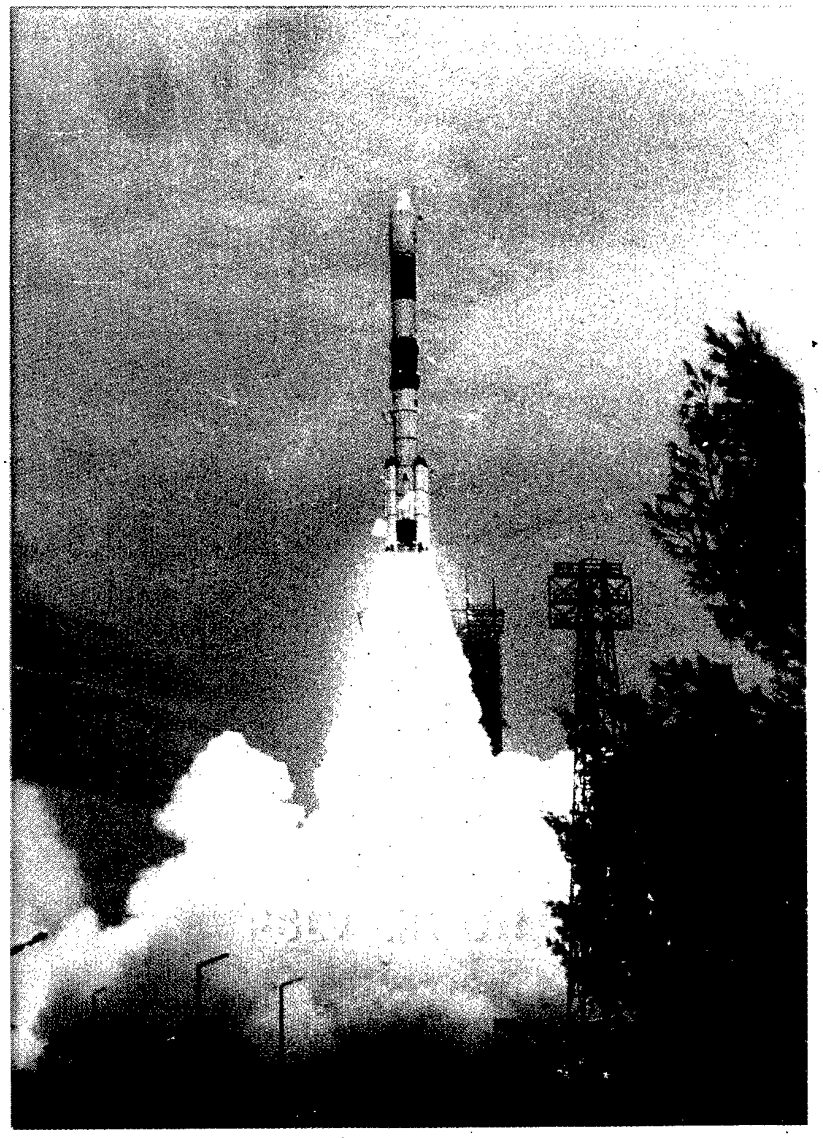

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